On the Minute Structure of *Stromatopora* and its Allies.

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(Plates I.–IV.)

Introductory Remarks.

The last decade, or thereabouts, has indeed witnessed vast changes in the opinions held as to the position and relationship &c. of several groups and so-called aberrant genera and species among the Invertebrates. This, to a great extent, has been brought about by the very considerable improvements in the modes of manipulation, investigation, and treatment of minute structure &c., and doubtless to the coordinate impetus given to the study of certain hitherto obscure forms, both as to their development and subsequent life-history.

The forms or groups of forms which constitute the basis of the present investigation have been regarded within the last fifty years in the most diverse aspects. *Stromatopora*, even at the present moment, occupies a most unsettled and uncertain position, while hints and doubts flow freely as to whether it be allied to the Calcareous or the Siliceous Sponges, to the Foraminifera, to the Corals, to the Hydrozoa, or to the Polyzoa, or whether it may not be a heterogeneous assemblage of dissimilar forms, or perhaps the representative of a special and now extinct group of organisms. Unfortunately the animal itself cannot be appealed to as affording evidence towards the solution of this problem, the remains of its habitation, or its skeletal structures, alone offering data upon which any judgment on this disputed point may be arrived at. The object, then, of this communication is to present the results of a careful examination of a large number of specimens and sections of different forms of *Stromatopora* and of related groups. These results, it is hoped, will serve to throw some light upon the anatomy and systematic position of the Stromatoporoids—though, as a matter of course, some points have necessarily been left doubtful or unsettled, to a large extent owing to the impossibility of obtaining access to many of the original specimens described by earlier observers.

In carrying out this investigation the materials at our disposal have consisted of a very extensive suite of specimens in various

states of fossilization, from the Lower and Upper Silurian and the Devonian rocks of Canada and the United States, specimens from the Upper Silurian and Devonian of Britain, and a few from the Upper Silurian deposits of Sweden. The great majority of these specimens have been personally collected by us, so that we are able to speak with precision as to the exact *gisement* of the specimens, and as to the condition of fossilization of the organic remains associated with them. A large number of the microscopic sections have also been personally prepared by us, and we are thus enabled to indicate with certainty their precise relations to the specimens from which they are taken*.

History and Literature.

As regards the history of the genus, the following are the principal works with which we are acquainted, or to which we have been able to obtain access during the course of our investigations, excluding memoirs wholly concerned with descriptions of species.

The genus *Stromatopora* was originally founded by Goldfuss ('Petrefacta Germaniæ,' 1826), and it was based upon the form which has been generally known as *Stromatopora concentrica*. At a subsequent page of the same work he describes another form under the name of *S. polymorpha*, and defines the genus, referring it to the Sponges. It is, however, now certain, as Roemer has shown by an examination of the original specimens of Goldfuss ('Lethæa Palæozoica,' 1877, explanation to pl. xxvi.), that these two species are identical; and though the latter form is described

* As this is a joint communication, it may be well to define to some extent how far each of the authors is responsible for particular parts of the work. One of the present writers (H. A. N.) had already devoted considerable attention to the Stromatoporoids, having published several memoirs on the group, and having arrived at tolerably definite views as to their structure and affinities, though these views were not based upon the examination of thin sections with the microscope. The great bulk of the material has also been collected and worked out by the writer just alluded to. On the other hand, his colleague brought to bear upon the subject a mind free from all preconceptions and prepossessions; and the entire question of the structure and affinities of this most difficult group of fossils has thus been most carefully debated and discussed between the two writers. This has involved extensive research on a number of collateral points, wherein each has furnished his quota. Nor need we shrink from stating that as fact after fact was accumulated, each has been obliged to shift his ground more than once before arriving at a final decision, the difficulties, as is so often the case, presenting themselves concomitantly with the increase of our knowledge.

most fully and from the best-preserved specimens, it must be abandoned in favour of the previously described *S. concentrica*. Still it follows from this that the type of the genus *Stromatopora* is not the entirely vague and undeterminable form which palæontologists have been in the habit of calling *S. concentrica*, but the well-marked and sharply characterized *S. polymorpha*.

De Blainville ('Manuel d'Actinologie,' 1834) refers *Stromatopora*, with doubt, to the Corals.

Steininger (Mém. de la Soc. Géol. de France, t. i., 1834) describes several species of *Stromatopora* from the Eifel limestone, and refers the genus to the Sponges.

Lonsdale (Trans. Geol. Soc. Lond. ser. 2, vol. v., 1840) places *Stromatopora* among the Corals; and he describes and figures a Stromatoporoid fossil under the name of *Coscinopora placenta*.

Professor Phillips ('Palæozoic Fossils of Cornwall,' &c., 1841) describes and figures some Stromatoporoids from the Devonian of Devonshire. He also founds the genus *Caunopora* for Lonsdale's *Coscinopora placenta*, and describes a new form of the same under the name of *C. ramosa*. As so many subsequent observers have done, Phillips regards the "radial" elements of the skeleton of *Stromatopora* as being *tubes*, a belief which is unequivocally disproved by microscopic examination, as first satisfactorily shown by Von Rosen.

In 1843, Ad. Roemer ('Die Versteinerungen des Harzgebirges') described some Stromatoporoids, placing one among the Sponges, and the rest among the Corals. In the same year Keyserling ('Reise in das Petschora-Land') expressed the opinion that the genus *Stromatopora* should be placed among the Corals, and that it is nearly allied to *Alveolites*, Lam.

In 1844, Ferdinand Roemer ('Das rheinische Uebergangsgebirge') published the opinion that *Coscinopora placenta*, Lonsd. (= *Caunopora placenta*, Phill.), is founded upon specimens of *Stromatopora* attached parasitically to a coral.

In 1844, Prof. M'Coy ('Synopsis Carb. Limestone Foss. of Ireland') described briefly some more or less obscure fossils from the Carboniferous Limestone of Ireland, to which he gives the names of *Caunopora placenta*, Phill., *Stromatopora concentrica*, Lonsd., *S. polymorpha*, Gold., and *S. subtilis*, M'Coy. The true structure and nature of these must remain at present doubtful.

In 1847, Hall ('Pal. New York,' vol. i. p. 48, pl. xii.) founded the genus *Stromatocerium* for a Stromatoporoid from the Trenton

Limestone of North America, the structural characters of the genus, however, being left undefined. In the same work (vol. ii. p. 135, 1852) Prof. Hall states that, according to his observations, the skeleton of *Stromatopora* is "composed of minute cylindrical tubes with considerable space between, and that the laminated structure arises from thin layers of calcareous matter deposited and filling the spaces between and filling the tubes." He considers the genus to be referable to the Corals, and to be "more nearly related to *Tubipora* than to any other genus."

In the 'Prodrome de Paléontologie' (1850), D'Orbigny places the genus *Stromatopora* among the Sponges, and gives short definitions of some species, founded, of course, upon macroscopic characters only. In the 'Cours Élémentaire de Paléontologie' (1851), the same observer again places the genus in the same systematic position. D'Orbigny's genus *Sparsispongia*, however, would seem to be founded upon Stromatoporoids of the type of, or identical with, *Stromatopora polymorpha*, Goldf.

In 1851, Prof. M'Coy ('Brit. Pal. Foss.' p. 12) expressed the opinion that *Stromatopora* is a true Coral, allied to *Fistulipora* and *Palæopora* (=*Heliolites*). His definition of the genus is:—"Corallum calcareous, forming large amorphous masses composed of very thin superposed layers of minute vesicular tissue of the thickness of one cell each, occasionally marked on the upper surface with extremely obscure, distant, quincuncially-arranged small pits."

The two Sandbergers ('Die Versteinerungen des rheinischen Schichtensystems in Nassau,' 1850–56, p. 380) consider that *Stromatopora* properly belongs to the Polyzoa; but they base this view upon the unquestionably erroneous interpretation of the "radial pillars" as being *tubes*.

The same view as to the affinities of *Stromatopora* is expressed by Professor Ferdinand Roemer ('Lethæa Geognostica,' 3rd ed. vol. i. p. 166), who compares the genus with the recent *Cellepora*; and who explains the apparent absence of "cells" upon the ground that perhaps these structures were extremely minute, or the cell-walls were very destructible. Roemer adds, however, that since he expressed this opinion, he has examined specimens of *S. polymorpha* from the Eifel, in which he can detect both prismatic tubes and tabulæ, and that the genus will therefore probably have to be removed to the "Tabulate Corals" and placed near *Chætetes* and *Favosites*.

Eichwald, on the other hand ('Lethæa Rossica,' vol. i. p. 345, 1860) defines *Stromatopora* as composed of a spongy mass constructed of closely approximated lamellæ and enveloping other organic bodies, its surface covered with minute rounded pores arranged without order over the whole surface of the skeleton, the latter being formed of a network of very minute horny fibres. M. Eichwald is thus the first, so far as we are aware, to promulgate the view, afterwards so strongly supported by Von Rosen, that the Stromatoporoids were really composed of horny fibres in their original constitution.

In 1866, Prof. Winchell ('Report on the Michigan Peninsula') described several species of *Stromatopora*; but we have unfortunately been unable to obtain access to this work for consultation.

In the 'Proceedings of the American Association' for 1866 the same author also defines the genus *Cœnostroma*, and discusses the affinities of the Stromatoporoids in general; but this memoir also we have unluckily been unable to consult.

The most important contribution to the structure and history of the Stromatoporoids is that published in 1867 by Von Rosen, under the title 'Ueber die Natur der Stromatoporen, und über die Erhaltung der Hornfaser der Spongien im fossilen Zustande.' In this work the author considers the structure of *Stromatopora* as elucidated by means of vertical and horizontal (or, better, "tangential") sections prepared for microscopic examination, and the highest praise must be accorded to his plates for their accuracy and fidelity to nature. We are not, however, able to agree with the main thesis of his valuable memoir, which he supports by evidence drawn both from the study of *Stromatopora* itself and from collateral sources, namely, that the skeleton of the Stromatoporoids was originally composed of minute horny fibres, which were replaced, in the process of fossilization, by carbonate of lime. We quite coincide, on the other hand, with the author's view, that the belief that the ordinary and typical Stromatoporoids were originally *siliceous* is not supported by the evidence at present in our hands.

In 1870, Dr. Gustav Lindström published an important paper on the Anthozoa Perforata of Gotland ('Kongl. Svenska Vetenskaps-Akad. Handlingar,' Bd. ix.), in which he describes and figures the *Porites discoidea* of Lonsdale as a Stomatoporoid under the name of *Cœnostroma discoideum*. He regards *Cœnostroma* as

a true coral closely allied to the existing Poritidæ; and he justly points to the close resemblance in appearance and general structure between *Cœnostroma* and *Psammocora*. While admitting this resemblance, the passage between *Cœnostroma* and *Stromatopora* proper is easily effected by means of forms like *Syringostroma*; and the minute structure of the former forbids our acceptance of the view that it can really be a coral. *Stromatopora* itself is regarded by Lindström as probably Foraminiferal.

In a paper on the affinities of the Anthozoa Tabulata (Œfversigt af Kongl. Vetenskaps-Akad. Förhandl. 1873, translated in Ann. & Mag. Nat. Hist. 1876), Dr. Lindström indicates that *Cœnostroma*, Winchell, which is an undoubted Stromatoporoid, presents certain affinities to *Labechia*, E. & H.; and he regards this latter genus as Hydrozoal, and as related to the recent *Hydractinia*. On this point, however, we shall have more to say hereafter.

In the 'Twenty-third Annual Report on the State Cabinet,' dated 1873, but, we believe, not actually published till 1874, Prof. Hall describes several species of *Stromatopora* from the Devonian rocks of the United States. In describing a species of *Caunopora*, Phill., he expresses some doubt as to the propriety of separating *Caunopora* and *Cœnostroma* from *Stromatopora* proper, upon the ground that both, when carefully examined, "prove to be made up of a series of vertical columns" (our "radial pillars") "connected by lateral filaments, which radiate more or less regularly at given intervals, and unite the several columns to each other, just as in the typical *Stromatopora*; and it is these lateral processes which in a vertical section give the appearance of horizontal plates."

In 1873, Salter expressed the opinion that *Stromatopora* is "a very solid calcareous sponge" ('Cat. Sil. Foss.' p. 99).

In 1873 (Ann. & Mag. Nat. Hist. ser. 4, vol. xii.) one of the present writers described several species of *Stromatopora* from the Upper Silurian and Devonian strata of Canada, indicating in one of them (*S. ostiolata*, Nich.) the presence of large apertures believed to correspond to the "oscula" of sponges.

In 1874, the same writer (Ann. & Mag. Nat. Hist. ser. 4, vol. xiii.) discussed the affinities of the genus *Stromatopora* upon general grounds, referring it to the Calcispongiæ, and indicating the presence in examples of various species of large "oscular" openings. The skeleton was regarded as "composed of an amalgamated system of horizontal spicules separated by interspaces and kept

apart by a vertical system of delicate calcareous rods, giving rise to a system of more or less quadrangular tubes." In the 'Report on the Palæontology of the Province of Ontario' (1874), the same opinion is repeated; and in the 'Palæontology of the State of Ohio' (vol. ii., 1875), the author describes several additional species of *Stromatopora*, and founds the genera *Syringostroma* and *Dictyostroma*.

In the 'Dawn of Life' (1875), Principal Dawson incidentally gives the result of his observations on the structure of *Stromatopora* and its allies, apparently regarding them as intermediate between the Foraminifera and the Sponges. This distinguished palæontologist further describes in *Caunopora* and *Cœnostroma* a system of tubes or groups of tubes which traverse the horizontal laminæ of the skeleton, and "in each successive floor give out radiating and branching canals exactly like those of *Eozoön*." From Dr. Dawson's description and figures, we should be disposed to imagine that in this statement he is referring to the comparatively large radiating and vertical canals which are present in most, if not in all, of the Stromatoporoids, and which are, as a rule, visible even to the naked eye. If, however, he is referring to any microscopic tubules at all comparable to the minute "tubuli" of the test of the perforate Foraminifera, then we can only say that though we have in some thin sections imagined that we had met with indications of such a tubulation of the skeleton, we have hitherto failed, after the most careful investigation, to satisfy ourselves as to the real existence of such a structure.

In a memoir upon *Stauronema*, a new genus of fossil Hexactinellid Sponges (Ann. & Mag. Nat. Hist. ser. 4, vol. xix.), Mr. Sollas places *Stromatopora concentrica* (under the new generic title of *Callodictyon*) among the Vitreo-hexactinellid sponges, in the family Aphrocallistidæ. In a subsequent paper ("The Structure and Affinities of the Genus *Siphonia*," Quart. Journ. Geol. Soc. 1877), the author says that he does not regard the genus *Stromatopora* as wholly referable to the Vitreo-hexactinellidæ, but that part is Hydrozoal and related to *Millepora* and *Hydractinia*, and that part belongs to other groups not yet determined.

Mr. Carter (Ann. & Mag. Nat. Hist. ser. 4, vol. xix. 1877) has expressed the opinion that *Stromatopora* and allies are closely related to the living genus *Hydractinia*, and that the extinct genus *Parkeria*, described by Dr. W. B. Carpenter as a Forami-

nifer, is also truly Hydrozoal and related to *Hydractinia*. Upon this point we must speak with considerable diffidence, as not having seen and examined the specimens upon which Mr. Carter's views are based. We have, however, examined a large series of specimens and sections of *Parkeria*, including typical examples kindly furnished us by Dr. Carpenter himself; and we believe the view that it is an Arenaceous Foraminifer to be the one most in accordance with the facts exhibited by these specimens. We quite admit the likeness in structure presented by some forms of *Stromatopora* to *Parkeria*; but having arrived at the conclusion that all the Stromatoporoids were primitively calcareous, we are unable to admit that there is any real affinity between these two groups of organisms. As regards the ordinary forms of *Hydractinia*, we can fully recognize the resemblance which these present to the Silurian fossils described by Milne-Edwards and Haime under the name of *Labechia*, a resemblance which, as we have already indicated, was long ago pointed out by Lindström, though even in this case the apparently solid pillars of *Labechia* can hardly be paralleled with any structure present in *Hydractinia*. We are not, however, so far as the extensive series of specimens which we have examined will allow us to judge, prepared to admit that any relationship of real affinity subsists between *Stromatopora* and *Hydractinia*, though the existence of calcareous species of the latter genus is certainly a noteworthy fact. As to the existence, lastly, of siliceous species of *Hydractinia*, such as described by Mr. Carter from the Upper Greensand of Haldon Hill, we think that it would be desirable to obtain more evidence than has yet been published, proving that such apparently siliceous forms are not merely *silicified* examples of originally calcareous specimens. We do not of course assert that this is the case; but we think that this is a consideration which cannot be overlooked in any discussion of this question.

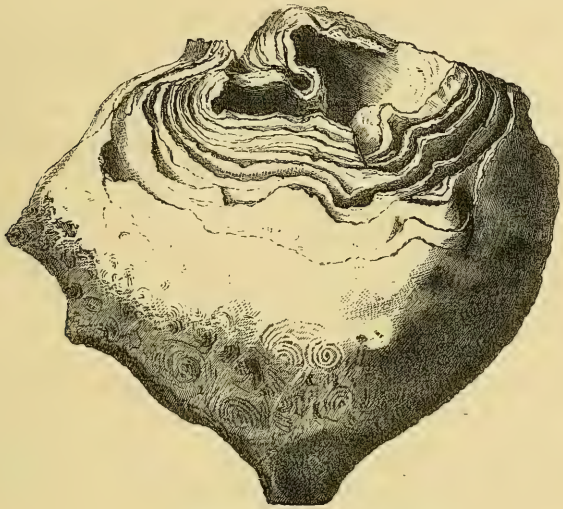
Lastly, Professor Zittel, in a supplementary note to the English translation (Ann. & Mag. Nat. Hist. ser. 4, vol. xix. 1877) of his masterly memoir entitled "Beiträge zur Systematik der fossilen Spongien" ('Neues Jahrbuch für Mineralogie,' &c. 1877), gives his adhesion to Mr. Carter's view that the Stromatoporoids are really to be regarded as allies of *Hydractinia*, and as belonging, therefore, to the Hydrozoa*.

* Since the above was written, the following additional papers upon the Stromatoporoids have been published or read:—

General Structure of a Typical Stromatopora.

If we take a typical species of *Stromatopora*, such as *S. concentrica*, Gold., of the Devonian, we find that it presents itself

Fig. 1.



Stromatopora rugosa.

A small and perfect specimen, of the natural size, from the Trenton Limestone of Canada. (After Billings.)

Dr. Steinmann has published a memoir, "Ueber fossile Hydrozoen" [Palæontographica, n. F. v. 3 (xxv.), p. 101], in which he refers *Stromatopora* to the Hydractiniidæ, and as being structurely similar to his new genus *Sphæractinia*.

Mr. Carter expresses the opinion that *Stromatopora* is identical in structure with the recent *Millepora alcicornis* (Ann. & Mag. Nat. Hist. ser. 5, vol. i. p. 298). A perusal of Mr. Carter's remarks will at once show that in speaking of "*Stromatopora*" he is really alluding only to the curious and aberrant *Caunopora*. In a second paper (ibid. p. 412) Mr. Carter announces that he has detected "hexactinellid structure" in *Stromatopora* from Devonshire, and in a third (ibid. vol. ii. p. 85) he says that the form presenting this structure is *S. concentrica*, and that he has determined this to be really *Caunopora*, Phill.

In a paper on the Microscopic Structure of the Stromatoporidæ, not yet published in full, Principal Dawson gives grounds for believing that the Stromatoporoids are truly Foraminiferal, and are the Palæozoic representatives of *Eozoön* (Abstract, Proc. Geol. Soc. No. 355, p. 4).

Finally, Mr. A. Champernowne (ibid. p. 5) gives an account of the Stromatoporoids of Devonshire, and his views as to their structure and nature.

in the form of rounded subhemispherical or irregularly spheroidal masses, or of flattened expansions of an incrusting character, composed of thin, close-set laminæ arranged concentrically round one or more centres. These concentric and fundamentally horizontal laminæ are separated by interspaces, which are crossed by more or less numerous vertical pillars, or, as we shall term them, "radial pillars." Hence the vertical section exhibits a number of approximately horizontal layers and intervening spaces, the latter divided by upright pillars into a number of minute vesicular compartments. In some instances the entire laminated mass has grown, as has often been described, in successive superimposed layers round some central nucleus, such as the shell of a mollusk or a coral; but this is by no means universally the case.

On the contrary, many examples were attached by a narrow base to some foreign body (such as a coral), developing upwards into a more or less extended expansion, the under surface of which is covered by a wrinkled and imperforate epithecal membrane.

Mode of Occurrence, Condition of Fossilization, and Original Constitution.

Stromatopora and its allies are found in detached masses or expansions, often of very considerable dimensions, and frequently in very great numbers in particular localities. They occur most commonly in limestones, associated with Corals, Brachiopods, and other marine fossils; but they also occur in argillaceous sediments. As to the condition of fossilization in which they occur, some specimens are calcareous, others are siliceous, others are partially calcareous and partially siliceous.

As to the *original constitution* of the hard structures of the Stromatoporoids, it has generally been assumed that the skeleton was calcareous. There are, however, four views which may be entertained on the subject:—

First. It may be held that *Stromatopora* was originally *calcareous*, and that all specimens which we now find in a more or less completely siliceous condition owe this to their having been more or less thoroughly subjected to the familiar process of "silicification."

Secondly. It may be held that *Stromatopora* was primitively *siliceous*, and that all calcareous specimens owe their present constitution to the fact that the original silica of the specimen has been replaced by carbonate of lime. Mr. Sollas (Ann. & Mag. Nat. Hist.

ser. 4, vol. xix.) would seem to be in favour of this view, at any rate in part.

Thirdly. As has been suggested to us by Dr. W. B. Carpenter, it is possible that amongst the *Stromatoporæ* and their allies were included organisms of essentially similar structure, but differing in the fact that some of them were siliceous and others calcareous (just as a similar series of morphological types can be shown to have existed amongst the arenaceous and calcareous Foraminifera).

Fourthly. It may be maintained, as was originally supposed by Eichwald ('Lethæa Rossica,' vol. i.), and as was afterwards so forcibly urged by Von Rosen ('Ueber die Natur der Stromatoporen,' 1867), that the skeleton of *Stromatopora* was originally horny, and that the primitive horny fibres were replaced by silica or by carbonate of lime. This view we shall not discuss further, as the researches of Zittel and Sollas have completely destroyed all the collateral evidence upon which Von Rosen founded his views, and which was essential to the support of his argument.

In deciding which of the above views is correct, we have three kinds of evidence to consider, namely the mode of occurrence of the Stromatoporoids in the beds in which they are found and the condition of their associated fossils; the microscopic appearances of transparent sections; and, lastly, the composition of different specimens, as shown by the effects produced by the application of acids and by other modes of examination.

The evidence under the first head is of great importance, and far too little attention has hitherto been paid to it. So far as the facts at present in our possession go, the general evidence is altogether in favour of the view that *Stromatopora* and its immediate allies were originally calcareous. The ground for this assertion is the fact that (within our experience) specimens of *Stromatopora* and its allies are always found in a calcareous condition when the associated fossils are also calcareous, but that they are generally more or less siliceous where the associated and primitively calcareous fossils are to any large proportion silicified. Excellent examples of this are afforded by the occurrence of Stromatoporoids in the Silurian and Devonian deposits. Thus in the Silurian Limestones (such as the Trenton, Niagara, and Clinton Limestones), in which silicification is comparatively infrequent, the specimens of *Stromatopora* are generally calcareous, and in the Magnesian Limestones of the Guelph formation (Upper Silurian)

they resemble the other fossils in being converted into dolomite. Again, in the cherty limestones of the Corniferous series (Devonian), we find numerous Stromatoporoids in a siliceous condition, and we find at the same time that nearly all the associated corals, Brachiopods, and other originally calcareous fossils have undergone silicification. If we ascend, however, into the immediately overlying shales and impure limestones of the Hamilton group, we find an abundance of Stromatoporoids (sometimes specifically identical with those of the Corniferous) in the same completely calcareous condition as all the other fossils of the formation. Similar facts seem to be observable elsewhere, as shown by the fact that the Stromatoporoids of the Wenlock Limestone of Dudley, the Wenlock Limestone of Gotland, and the Devonian Limestones of Devonshire resemble the fossils associated with them in being calcareous*.

The microscopic characters of thin sections afford comparatively little help in determining whether *Stromatopora* was originally calcareous or siliceous. In no case, however, have we succeeded in observing that the laminæ or pillars were composed of distinct and separate siliceous granules; nor can any structure of a similar nature be detected by the microscope in siliceous examples of *Stromatopora* from which the matrix has been completely removed by the action of weathering or the use of acids. Such a construction, however, is very readily observable in the case of *Parkeria*.

Another fact of a very noteworthy character is brought out by an examination of thin sections of the Stromatoporoids with the microscope. In all cases alike, namely, whether the specimen be purely calcareous or partly calcareous and partly siliceous, the carbonate of lime forming the actual skeleton is invariably *granular*. In other words, the skeleton is never composed of crystalline calcite, but always of the granular ill-defined calcareous matter which we find also in the skeleton of the ordinary corals. The importance of this observation is much enhanced by the discovery made by Zittel (Neues Jahrb. für Mineralogie, &c. 1877) that

* Since writing the above, we have personally visited the Devonian Limestones of Devonshire, the Upper Silurian Limestones of Wenlock Edge and Woolhope, and the great "Eifelkalk" of Germany, from all of which we have made large collections of Stromatoporoids; and in all these localities we find the above conclusions confirmed in all particulars. That is to say, the Stromatoporoids are invariably calcareous where no silicification of the associated corals and shells has taken place.

some of the true siliceous Hexactinellid Sponges have their skeleton replaced by carbonate of lime, but that in these cases the replacing material has the form of *crystalline calcite*. This, therefore, we should be justified in expecting to find also the case if the Stromatoporoids had been primitively siliceous and had been replaced by lime; but in reality the calcareous skeleton is under no circumstances, so far as we have observed, crystalline. On the other hand, the granular appearance of the carbonate of lime is a very strong proof that it constituted the primitive skeleton of the Stromatoporoids.

As regards the actual *condition of preservation* in which specimens occur, we find that there are five different states in which the Stromatoporoids are found:—

(*a*) In the first place, many specimens not only have the skeleton entirely calcareous, but have the sarcode-chambers further filled with calcareous matter in the form of transparent calcite. This is the case with all specimens from beds where the fossils generally are unaltered, as in the Dudley Limestone (Wenlock) and the corresponding limestones of Gotland, as well as in the equivalent Niagara Limestone of North America. It is also the case, essentially, with the Stromatoporoids of the Guelph Limestones and of the Clinton formation of North America, though in these the sarcode-chambers are filled with a crystalline aggregate of dolomite instead of calcite.

(*b*) In the second place, many specimens are found in which the skeleton of the fossil is more or less completely calcareous, whilst the sarcode-chambers are infiltrated more or less completely with silica. When this is the case, decalcification, whether natural or artificial, and whether applied to thin sections, to polished surfaces, or to small fragments, results in the production of a siliceous structure representing the casts of the sarcode-chambers and interlaminar spaces, together, in some cases, with the canals connecting these. Transparent sections of similar specimens show, as a rule, however, that the infiltration with silica has not been absolutely perfect. On the contrary, the porous skeleton of the fossil seems to have been first infiltrated with water holding carbonate of lime in solution, resulting in the deposition of a thin layer of small crystals of calcite throughout the whole of the sarcode-chambers, and the space still left empty was subsequently filled with silica. This is beautifully shown by the polariscope in specimens of this nature, the actual calcareous

skeleton, with its delicate layer of calcite-crystals, remaining unchanged, whilst the siliceous infilling of the chambers is brilliantly coloured. Specimens of this kind, infiltrated with silica, but having their actual skeleton unchanged, are very common in the Corniferous Limestone of North America.

These specimens, moreover, prove the important fact that the silica filling the chambers and interspaces of the fossil is not amorphous organic silica, but crystalline doubly-refractive silica; for the use of crossed prisms produces the most brilliant play of colours in the siliceous infilling of the chambers, the variety and intensity of tints being fully equal to what we observe in crystals of quartz.

(*c*) In the third place, we find specimens in which the actual skeleton of the fossil is more or less completely converted into silica (often faintly granular under the microscope), whilst the chambers of the organism are filled with calcite. In these specimens decalcification, whether natural or artificial, results in the production of a reticulated siliceous framework, representing the true skeleton, the interspaces being hollow. Specimens of this kind are not unknown in the Corniferous Limestone of North America; but they lend no support whatever to the view that *Stromatopora* was originally siliceous, for this is precisely the state of preservation in which almost all the fossils of the Corniferous Limestone occur, such as Corals, Brachiopods, &c., which were undoubtedly calcareous to begin with. All these fossils, namely, have their primitively calcareous structure accurately replaced by silica (often of a granular appearance), whilst their cavities are filled with carbonate of lime. It should also be noticed that small specimens in this state of preservation, especially specimens mounted for microscopic examination, are not easily discriminated from similar fragments of specimens of the second group, where the skeleton is unaltered and the chambers have been filled in with silica. This is especially the case when decalcification, natural or artificial, has been produced, as the resemblance of the true silicified skeleton to the siliceous network representing the successive tiers of sarcode-chambers is much closer than might be imagined. It may safely be asserted, indeed, that it would be very difficult for any observer to discriminate with certainty between microscopic preparations belonging to these two groups unless he had previously seen the actual specimens from which they were taken, if it were not absolutely impossible. Against

this source of error, however, we have guarded by the personal preparation of our slides from specimens which we had previously subjected to a careful examination by means of polished sections and acids.

(*d*) In the fourth place, there occur specimens (especially in the Corniferous Limestone of North America) which unite in themselves both the last-mentioned states of preservation, the skeleton of the fossil in parts being calcareous, whilst the sarcode-chambers are infiltrated with silica; whereas in other parts the skeleton is siliceous and the chambers are filled with calcite. Specimens of this nature require no further notice here, as they teach us nothing that cannot be learned from an examination of specimens of either the second or third group.

(*e*) In the fifth place, we find a few examples in which not only is the skeleton siliceous, but the sarcode-chambers are likewise filled with silica. In these cases, of course, thin sections constitute the only mode of examination, as acids are wholly ineffective.

As regards the general conclusion to be drawn from the various classes of facts above enumerated, it appears to us to be unquestionable that the Stromatoporoids were originally *calcareous* in their composition. This conclusion seems to us to be rendered inevitable when we consider that specimens of the Stromatoporoids are almost invariably calcareous in beds in which the accompanying fossils are also generally unaltered, and that they are only found to be siliceous in strata in which the other fossils (undoubtedly calcareous to begin with) are silicified—that in no case known to us does microscopic examination show the skeleton to be composed of distinct siliceous spicules or of separate sand-grains—that many specimens are found in which the original spaces of the fossil are filled with silica, whilst the skeleton itself is more or less entirely calcareous—and that in many cases the original calcareous skeleton has clearly been coated to its most minute recesses with minute crystals of calc-spar before being finally infiltrated with silica. If we were to believe that *Stromatopora* was originally and essentially siliceous, we should have to believe that it had been, in innumerable instances, converted into *lime*. The researches of Zittel ("Die Hexactinelliden," Abhandl. der k. bayer. Akad. der Wiss. 1877) and of Sollas ("On *Stauronema*," Ann. & Mag. Nat. Hist. ser. 4, vol. xix. 1877) have, indeed, shown that the Hexactinellid sponges are occasionally more or less completely converted into carbonate of lime; so that

palæontologists can no longer refuse to recognize and take into account the possibility of the replacement of silica by carbonate of lime. In this particular case, however, we should be compelled to believe that this certainly unusual conversion of a siliceous skeleton into a calcareous one had taken place just in the very beds in which the fossils, as a rule, show no alteration whatever—beds like the Wenlock Limestone of Britain and Sweden, and the Trenton and Niagara Limestones and the Hamilton formation of North America. On the other hand, when we meet with Stromatoporoids with a siliceous skeleton, we should have to believe that this was their original constitution, and we should have to account for the fact that these siliceous specimens are almost, if not quite, exclusively found in strata in which the unquestionably calcareous corals and Brachiopods are for the most part also siliceous. The only other hypothesis, namely that the Stromatoporoids (like the Foraminifera) are sometimes calcareous and sometimes siliceous, we were at first not indisposed to accept; but the total absence of any composition out of distinct sand-grains in the silicified specimens, and the existence of specimens partly silicified and partly calcareous, have induced us to abandon this view. This view, however, might be easily entertained if due care were not taken to separate specimens showing the siliceous infilling of the sarcode-chambers from those in which the skeleton itself has been silicified.

Minute Stucture of the Stromatoporoids.

In studying the minute structure of any Stromatoporoid, it is necessary to make sections in two directions—namely, *vertically* or *radially*, at right angles to the concentric laminæ of the mass, and *horizontally* or *tangentially*, or parallel with the concentric laminæ *. Sections of the first order are easily prepared; but sections of the second order present greater difficulties, as the concentric laminæ are invariably more or less curved or undu-

* Owing to the very variable form of the colonies of the Stromatoporoids, the terms *vertical* and *horizontal* can hardly be used with propriety to designate the two kinds of sections above referred to, unless they are understood simply as expressing the relation of the sections to the concentric laminæ of the fossil. We prefer, therefore, to use the terms "*radial*" and "*tangential*," the former indicating all sections which are parallel with the "radial pillars," and which cut the concentric laminæ at right angles, whereas by the latter we understand all sections which are approximately parallel with the concentric laminæ, whatever may be the relation between the planes of these sections and the plane of the general mass from which they are taken.

lated, and it is impossible to make a section wholly in the plane of any single lamina or interspace.

In studying the minute structure of the Stromatoporoids, we have successively to consider the following points :—

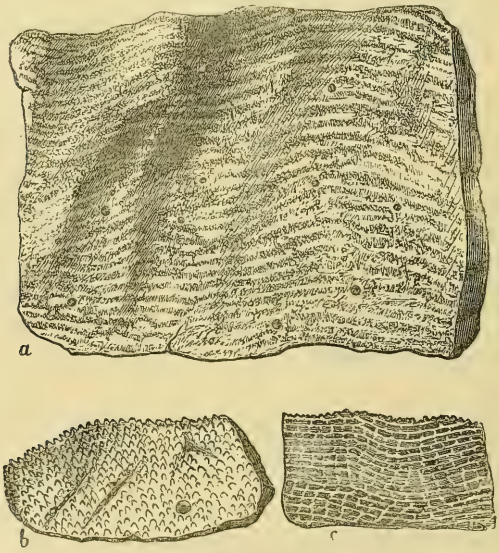
1. *The Internal Constitution of the Mass.*—If we make a *vertical* or *radial* section of any typical Stromatoporoid, such as *Stromatopora concentrica*, Goldf., we find that it is composed of curved, undulating, but essentially horizontal "laminæ," either spread out in mass or arranged concentrically round one or more centres, and having wider or narrower interspaces between them. The latter are crossed by vertical or "radial" pillars, placed at approximately similar distances, and dividing the "interlaminar spaces" into a number of minute compartments. A *horizontal* or tangential section of a similar form shows the transversely divided ends of the "radial" pillars, along with winding or reticulated lines representing the obliquely cut edges of successive undulating laminæ belonging to the horizontal series. In their *ultimate constitution* both the horizontal laminæ and the "radial" pillars are composed of minutely granular carbonate of lime, which shows no structure beyond the occasional presence of an indistinct reticulation, and which is entirely unaffected by polarized light. In sections of calcareous specimens, when of great thinness, the laminæ become more or less indistinct as a rule, and it is only in certain cases that they show perfectly distinct and defined outlines and do not exhibit blurred edges *. In some silicified specimens, on the other hand, the skeleton is brought out with great vividness between crossed Nicols, since it remains unaffected itself, whilst the filling of the spaces of the fossil exhibits a brilliant play of colours. Even in these cases, however, the actual laminæ and pillars are often invested by an irregular crystalline layer or coating of carbonate of lime, which remains uncoloured.

2. *The Nature of the Radial Pillars.*—The vertical or radial pillars of a typical Stromatoporoid have most generally been regarded as *tubes*. So far, however, as all ordinary examples go, we can entirely confirm Von Rosen's observations ('Ueber die Natur der Stromatoporen,' 1867), which clearly show that these pillars are

* For this reason, in dealing with the calcareous Stromatoporoids (as apart from silicified specimens), the best results are obtained when the section has not been cut down to an excessive degree of tenuity, and when a low magnifying-power (a 2 to 4-inch objective) is used.

solid and imperforate. In no case have we certainly succeeded in detecting any central cavity in the radial pillars, when their truncated ends are examined in tangential or oblique sections. The tubercles which stud the surface of many forms are sometimes seen to be perforated by a central aperture; but we have never noticed this appearance except upon the weathered and partially exfoliated surface of *silicified* specimens, and even in these many of the tubercles in question are undeniably imperforate. We are therefore disposed to explain this appearance as being due, not to the real existence of a central canal in the radial pillars, but rather to the fact that the pillars have been imperfectly silicified, and the unchanged carbonate of lime in their interior has been subsequently dissolved out. In general form, the radial pillars are usually expanded at the points where they coalesce with the horizontal laminæ which they connect, and attenuated in their central portions, and, though occasionally oblique, they mostly have a vertical direction. In some cases they are partially rudimentary,

Fig. 2.



Stromatopora tuberculata.

a. Under surface, of natural size, showing the wrinkled basement-membrane and openings of water-canals. *b*. Portions of upper surface, enlarged. *c*. Vertical section, to show internal structure, magnified. From the Corniferous Limestone, Canada. (After Nicholson.)

falling short of the horizontal lamina above that from which they spring. In such cases they appear in weathered specimens as so many elevated tubercles on the surfaces of the laminæ. In some cases, which will be afterwards alluded to, they are replaced by downward inflexions of the horizontal laminæ themselves; and in some aberrant forms, which will be noticed hereafter, they are entirely absent. Though they may be accidentally superimposed upon one another in successive interlaminar spaces, they are clearly independent of one another in origin, and are severally confined to their own interspaces. Even, therefore, if they were perforated centrally, they could not be compared properly with the tubes of *Tubipora* or *Fistulipora*.

3. *The Structure of the Horizontal Laminæ.*—The horizontal laminæ which form the greater part of the mass of a typical Stromatoporoid appear in vertical sections as so many continuous concentric layers, whilst in horizontal sections they are necessarily only visible where their cut edges may be brought into view in consequence of their undulations. They can therefore be only to a certain extent studied by means of thin slices prepared for the microscope, since vertical sections simply cut them transversely and leave many points unelucidated; whilst horizontal sections cannot be made to show more than the most minute portions of the surface in the plane of any single lamina. We have therefore to rely principally upon the appearances presented by the horizontal laminæ as exposed on the surface of unaltered calcareous specimens, or, still better, as seen in weathered or decalcified specimens in which the skeleton has been silicified. Even when examined, however, both by sections or by weathered specimens, even when beautifully preserved, the horizontal laminæ do not present such clear or such uniform appearances that a positive opinion as to their minute structure can be rashly formed. On the contrary, it would appear that the actual structure of the horizontal laminæ is different in different Stromatoporoids.

In a great many Stromatoporoids (such as *Stromatopora striatella*, D'Orb., *S. granulata*, Nich., *S. tuberculata*, Nich., &c.) the surfaces of the horizontal laminæ as exposed on weathered surfaces are seen to be studded with elevated granules or tubercles, sometimes extremely minute, sometimes large, papilliform, and prominent. These elevations are sometimes simply rounded; at other times they are confluent, and form vermiculate

eminences. Some of them are apparently broken radial pillars, and perhaps they are in general incipient structures of this nature. Most of these tubercles are clearly imperforate; but it is not uncommon in silicified examples, as before remarked, to find a variable number of the tubercles perforated by a central tube. If these tubes are natural, then they must serve to place the successive interlaminar spaces in communication; but, as above stated, we have only detected them in silicified examples, and we are inclined to think that they are due to imperfect silicification. In the tuberculate Stromatoporoids just alluded to (such as *S. granulata*, Nich.), whether we take calcareous or silicified examples, and however exquisite may be the state of preservation, we have hitherto failed to satisfy ourselves of the existence of any openings piercing the laminæ between the tubercles, and placing successive interlaminar spaces in communication, though it seems most likely that such really exist.

On the other hand, there are forms (such as *Stromatopora nodulata*, Nich., and *Syringostroma densa*, Nich., and various forms from the Devonian limestones of Devonshire and of the Eifel) in which the surfaces of the horizontal laminæ are smooth and exhibit no tubercles, while they are rendered minutely porous by the presence of innumerable apertures. These openings may be extremely minute, or they may be of comparatively large size and of a vermiculate character, in which latter case the horizontal laminæ assume a kind of trabecular or loosely reticulate structure. There cannot, therefore, be in these cases any doubt that the interlaminar spaces communicate with one another directly by canals passing vertically through the horizontal laminæ, and entirely independent of the radial pillars. That some such communication, to a greater or less extent, exists in all the Stromatoporoids appears to be exceedingly probable, though we have failed to satisfy ourselves of its existence in some forms. One of the difficulties connected with this is that of demonstrating any perpendicular tubules passing through the horizontal laminæ in *transparent vertical slices* of the fossil. Sections of this nature *ought* to show these tubuli if they are present at all. In very many cases, especially in unaltered calcareous specimens, the substance of the horizontal laminæ in very thin sections becomes so ill-defined that, even by the use of the polariscope, it is impossible to make out whether tubules are present or not. Even in cases where we *know* that the interlaminar spaces communicate

in this manner (as in *S. nodulata*, Nich.), thin vertical sections afford no conclusive evidence of the existence of these connecting-tubes—the cut edges of the horizontal laminæ appearing as granular or subreticulate *continuous* lines, with only occasionally faint indications of a vertical tubule marked out by clear calcite. In *Syringostroma densa*, again, where the horizontal laminæ are similarly perforate, the substance of the fossil is so dense that the evidence of vertical tubules is unsatisfactorily shown by vertical sections, though there are undoubted indications of their existence. There are also indications of the presence of similar vertical tubes in *Clathrodictyon cellulosum*, Nich. & Murie, though these also are but obscurely marked. Some further evidence on this point (though likewise unsatisfactory) may be derived from the examination of specimens which have preserved their calcareous skeleton but have had their sarcode-cavities infiltrated with silica. If we examine a vertical polished section of such a specimen by means of a strong light reflected from the surface, and by the help of a lens, we can sometimes satisfy ourselves that the sarcode-chambers of successive interlaminar spaces are connected by perpendicular tubuli which have been filled with silica, and thus take on a higher polish than the calcareous and unchanged skeleton itself. In decalcified examples of similar specimens it is also sometimes possible to trace minute threads of silica proceeding from the rounded masses of silica which represent the original sarcode-chambers. This we observed with especial distinctness in a specimen belonging to Principal Dawson, which Dr. W. B. Carpenter was so kind as to allow us to examine.

Another question of importance is as to whether the horizontal laminæ possess any system of tubuli running horizontally, and therefore approximately parallel with their surfaces, in their actual substance. Our investigations on this point lead us to believe that no such canal-system exists in the substance of the concentric laminæ. In some specimens, in which the skeleton has been silicified and the calcareous filling of the chambers has been dissolved out, the cut edges of the laminæ as exposed in vertical sections have a cellular structure, but it cannot be said whether this is due to the presence of horizontal tubules or to the existence of the vertical tubules before mentioned, or whether, rather, it may not be due simply to imperfect silicification. The last view seems to us most probable. Many forms, again (such as the species of *Syringostroma* and *Cœnostroma*), possess a system of branched

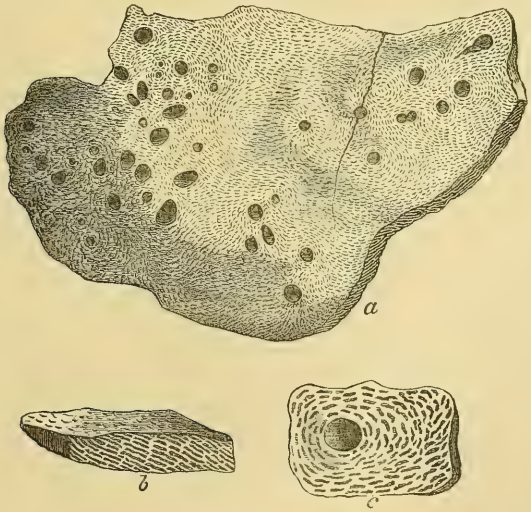
or radiating canals or grooves which are approximately horizontal, and which are arranged in minor systems round numerous secondary centres. These canals or grooves, however, as we shall hereafter show, have no distinct walls, are of comparatively large and not microscopic dimensions, and perforate the horizontal laminæ obliquely, a large portion of their course being thus in the interlaminar spaces. In fact they appear to be often confined to a single interlaminar space, and thus to be more of the nature of branched *grooves* on the surfaces of the horizontal laminæ than actual canals. In no case, certainly, do these canals run *in* the horizontal laminæ, so that they do not constitute a canal-system comparable to microscopic tubuli of certain of the Foraminifera. Principal Dawson ('Dawn of Life,' p. 159) describes a specimen of *Cœnostroma* in which "the plates are traversed by tubes or groups of tubes, which in each successive floor gave out radiating and branching canals exactly like those of *Eozoön*, though more regularly arranged." We have not, however, seen any traces of these in any of the specimens which we have examined; and it is possible that Dr. Dawson is merely alluding to the radiating canals which are found in *Cœnostroma*, *Caunopora*, and other forms, and which, as we have remarked, do not properly form a canal-system in the substance of the skeleton of the fossil itself.

4. *The Sarcode-chambers.*—The general form and arrangement of the sarcode-chambers of the typical Stromatoporoids can be best studied in naturally or artificially decalcified specimens in which the skeleton has been silicified, or, on the other hand, in decalcified specimens in which the skeleton has remained calcareous whilst the cavities have been infiltrated with silica. In the first class of specimens we find the horizontal laminæ to be separated by spaces of very various width in different species, these interspaces being in turn broken up at shorter or longer intervals by the radial pillars. In the second class of specimens we get *casts* in silica of the sarcode-chambers, and we can thus study their general form and arrangement more minutely. In these specimens we find that each interlaminar space, though on the whole continuous, is really composed of a number of separate rounded chambers, connected by wide openings and marked off by the radial pillars. Hence the siliceous cast of a single interlaminar space presents us with a layer of rounded oval or circular siliceous masses, connected with one another on all sides by stolons of silica of considerable size, and separated by small perforations

placed at their angles, these latter being the vacant spaces left by the dissolution and removal of the radial pillars.

5. *Radiated Water-canals.*—In a large number of Stromatoporoids the entire mass is perforated at intervals by numerous systems of horizontal or slightly oblique water-canals, as has been already alluded to. These canals usually radiate from a large number of independent centres, each of which is elevated above the surface, in many instances, as a conical eminence of greater or less height. In weathered specimens in which the surface is shown, or in horizontal section, these canals are often admirably displayed, and they are seen to bifurcate frequently as they diverge from their respective centres. We have not been able to show that they start in a median canal except in some cases; and though their course is approximately parallel with the concentric layers of the mass, they are usually slightly oblique, and therefore pass from one interlaminar space to another, perforating the laminæ themselves in an oblique manner. They are not bounded by definite walls, and they can hardly be regarded in any proper sense as being canals which run in the actual skeleton. These

Fig. 3.



Stromatopora Hindei.

a. Upper surface of a portion, natural size. *b.* Vertical section of same, showing internal structure, enlarged. *c.* Enlarged view of a piece of the upper surface. From the Niagara Limestone. (After Nicholson.)

radiating canals have been considered a generic character (distinguishing *Cœnostroma*); but they are present in forms of very different affinities, and it does not appear to us that they can be used as a ground of generic distinction. They are especially well developed in forms such as *Stromatopora constellata*, Hall, *S. typica*, Von Rosen, *S. astroites*, Von Rosen, *S. elegans*, Von Rosen, *S. Schmidtii*, Von Rosen, *S. granulata*, Nich., *Caunopora planulata*, Hall & Whitf., *Stromatopora* (*Cœnostroma*) *incrustans*, H. & W., *S.* (*Cœnostroma*) *solidula*, H. & W., *Syringostroma densa*, Nich., and *Syringostroma columnaris*, Nich., &c. In the forms which one of us has termed *Syringostroma* (Nich. Pal. Ohio, vol. ii.) these radiating canals are of specially large size, and in vertical sections their cut ends are conspicuously seen as so many large rounded apertures.

6. *Vertical Water-canals.*—Many Stromatoporoids show superficial openings of very considerable size, which are apparently the apertures of canals leading through the mass in a direction upon the whole more or less perpendicular to the concentric laminæ of the mass. These canals have no distinct walls, and their apertures vary in size from half a line or less up to a line or more. Their function can hardly be any other than that of conducting the external water into the interior of the mass, or, as is more probably the case, of carrying off the water which has circulated through the colony, and their external openings have been compared with the "oscula" of the Sponges. In many forms these openings have not been detected at all; but they are very well marked in others (*e. g.* in some specimens of *Stromatopora striatella*, D'Orb.?, in *S. Hindei*, Nich., *S. tuberculata*, Nich., *S. ponderosa*, Nich., and *S. ostiolata*, Nich.)*.

In a hitherto undescribed Stromatoporoid from the Trenton Limestone, which appears to be clearly of generic importance (*Stromatocerium*, Hall?), the entire mass is perforated by vertical canals, which are destitute of walls, and which are placed close together and appear to communicate with large and irregular lacunæ in the mass, now filled with calc-spar. As will be subsequently mentioned, this singular form differs from all the normal Stromatoporoids, not only in the number and closeness of the canals just spoken of, but also in the total absence of vertical

* These tubes have been supposed to be simply the work of boring Annelids or other organisms; but we cannot accept this view, and their number and regularity of arrangement in *S. ostiolata*, Nich., would conclusively prove that they belong, whatever their nature may be, to the Stromatoporoid itself.

pillars crossing the interlaminar spaces, and in some other characters as well. Having seen no example of this species in which the surface is weathered, we are unable to say how these canals appear superficially; but in horizontal sections they seem to be generally oval or elongated canals or wall-less spaces, freely opening into the interlaminar spaces.

7. *Tubes of* Caunopora.—Of a very different character to the preceding are the vertical tubes found in the genus *Caunopora*. The only example of this genus that we have been able to examine by means of microscopic sections is *Caunopora placenta*, Phill., from the Devonian rocks of Devonshire. In this form the general structure of the mass is very similar to that of a typical *Stromatopora*, such as *S. striatella*, D'Orb., except that the radial pillars are not so well developed. There is, however, the special feature that the entire mass is perforated by numerous discontinuous (?) vertical tubes penetrating the horizontal laminæ at right angles. These tubes have strong calcareous walls, are about $\frac{1}{2}$ line in diameter, have no vertical septa, but sometimes exhibit transverse calcareous plates, which look like continuations through them of the horizontal laminæ. The tubes are also sometimes connected by transverse tubular canals of considerable size. From the general form of these tubes, from their strong calcareous walls, and from the occasional presence of lateral connecting-tubes, we were led to think it possible that *Caunopora* might have been founded upon species of *Stromatopora* which had grown round and gradually enveloped a colony of *Syringopora*. Some silicified specimens of a *Caunopora* from the Devonian of Canada certainly look very like this. The tubes of *Caunopora*, however, are hollow, or at most have a few simple transverse tabulæ; and we have seen no traces in them, either in vertical or horizontal sections, of the *infundibuliform tabulæ* so characteristic of the *Syringoporæ*. We have also many silicified specimens of *Caunopora* (*Stromatopora*) *perforata*, Nich., in which the surface, with the openings of these tubes, is well seen. In this species, the entire fossil forms a thin and extended expansion, and the mouths of the tubes are all slightly elevated above the surface. Had the fossil grown round a pre-existent *Syringopora*, it is hardly possible for it to have presented these characters.

For the above reasons we are inclined at present to reject the view originally put forth by Ferd. Roemer, and subsequently adopted by Von Rosen, that *Caunopora* is founded upon Stroma-

toporoids which have grown parasitically upon colonies of *Syringopora*. At the same time, we desire to speak with diffidence upon this point, as we should require more material than has as yet been available to us before arriving at a final and positive conclusion*.

8. *Concentric Arrangement of the Chambers round Vertical Columns.*—Most of the Stromatoporoids show a tendency to a concentric arrangement of the horizontal laminæ round an indefinite number of minor centres, this being especially well seen in weathered and silicified specimens, though others exhibit little or nothing of this peculiarity. In *Syringostroma columnaris*, Nich., however, and in an undescribed Stromatoporoid (which we shall name *Stylodictyon retiforme*) from the Hamilton formation of Canada, this tendency is especially well marked, and is accompanied by the feature that the minor centres round which the chambers are arranged have the form of vertical columns, which run through the mass in a perpendicular direction and attain a very considerable size (from $\frac{1}{2}$ to 1 line in diameter). In the Hamilton species just mentioned, these columns (which must not be confounded with the vertical pillars crossing the interlaminar spaces) are composed of reticulate calcareous matter, more dense by far than the general mass, and sometimes traversed by a vertical canal in the centre. In *Syringostroma columnaris* the columns are composed centrally of granular calcareous matter, apparently quite imperforate and not reticulate, placed on an average about one line apart. Whatever be the minute structure of the columns, the chamberlets are arranged round them (as seen in horizontal sections) in from two to four concentric rows, the interspaces between these being filled up with the ordinary reticulate structure of *Stromatopora*.

9. *Departures from the ordinary Type of* Stromatopora.—All the typical forms of the Stromatoporoids, as we have seen, are composed essentially of a system of more or less porous or reticulate horizontal layers separated by interlaminar spaces, which in turn are crossed by numerous solid calcareous pillars having a vertical or radial direction. There are, however, several departures from

* Since the above was written we have obtained a very extensive series of *Caunoporæ* from the Devonian Limestone of Devonshire. These we have not yet had time to investigate microscopically; but an examination of their characters, especially as shown by cut and polished specimens, enables us to affirm with certainty that the tubes of *Caunopora* unquestionably belong to the organism itself, and that they have no connexion whatever with *Syringopora*.

this state of things amongst fossils clearly referable to the same great systematic group, the following being the most important:—

(*a*) In a Stromatoporoid already referred to from the Trenton Limestone of North America, we find various remarkable peculiarities. In the first place, whilst the general aspect of the fossil is unmistakably Stromatoporoid, we find that it possesses only the crowded concentric laminæ which characterize the typical Stromatoporoids. These horizontal laminæ are of considerable thickness, and are separated, as usual, by well-marked interlaminar spaces; but the latter are quite open, and there is a total absence of the vertical or radial calcareous pillars which occur in the normal Stromatoporoids. Not only are the radial pillars absent, but the whole mass is perforated by innumerable vertical canals, which are *destitute of walls*, and which open directly into the successive interlaminar spaces, which they penetrate, as well as into irregular open spaces or lacunæ in the general laminated skeleton. As seen in vertical sections, this form differs from the normal Stromatoporoids in the absence of the radial pillars and in the presence of the numerous vertical and large-sized canals which divide the horizontal laminæ into so many short sections of an oblong form; whilst in horizontal slices we no longer see the truncated ends of the radial pillars. On the contrary, horizontal sections show us nothing but the irregularly and obliquely-cut edges of the horizontal laminæ, often arranged concentrically round minor centres, and sometimes showing indications of a minute canal-system traversing their substance. This form is tolerably abundant in the Trenton Limestone, and we have obtained it from several localities. It is clearly generically distinct from the normal Stromatoporoids, and must receive a distinct name. It is, however, very probably the form upon which Hall founded his genus *Stromatocerium*, and we would propose to revive this name for it. Hall's *Stromatocerium rugosum* was obtained from the Birdseye Limestone of the State of New York, which is only a subdivision of the Trenton; and as we are acquainted with no typical form of *Stromatopora* (indeed with none but this) as occurring in this formation, it is highly probable that our specimens are identical with this. Hall abandoned his generic title simply from the general resemblance of his specimens to *Stromatopora*, in the broad sense of the term; and our specimens certainly cannot be referred to *Stromatopora* in the restricted sense of the name. Whether our form is specifically identical with Hall's *Stromato-*

cerium rugosum or not, is a point which we have no means of determining.

(*b*) Another singular form, which we propose to distinguish by the generic title of *Pachystroma*, and of which we possess many specimens from the Niagara Limestone of Canada, though clearly Stromatoporoid in its general characters, exhibits features even more singular than the preceding. The fossil exhibits the general form of the Stromatoporoids, consisting of irregular subhemispheric masses, composed conspicuously of numerous concentric calcareous layers; but these layers are of comparatively enormous thickness (averaging about a line, but sometimes double this thickness), and though perfectly distinct from one another, they are either in direct contact, or they are only separated from one another by irregular and narrow intervals. There are therefore no "interlaminar spaces" in the proper sense of the term, and necessarily no "radial pillars." When examined by means of transparent vertical sections, the great concentric laminæ are seen to be composed of porous calcareous tissue, principally composed of vertical irregular fibres placed at some distance from one another, and only brought clearly into view by the use of polarized light. The concentric laminæ are also perforated by numerous delicate, but irregular and generally remote, vertical tubules; but their surfaces, as seen in fractured or weathered specimens, cannot be shown by the use of a hand-lens to be minutely porous, though doubtless really so. The surface of weathered specimens also shows radiating, branched, "subdermal" canals, placed round numerous independent centres, precisely as in the so-called *Cœnostromæ*. Horizontal sections show simply a loosely reticulate calcareous network, of an irregular character and granular structure, with oblique sections of the radiating water-canals. In these, however, as in so many of the thin sections of the calcareous specimens of the Stromatoporoids, the use of polarized light is almost essential to a proper determination of the intimate structure.

(*c*) In another group of unquestionable Stromatoporoids, the general structure is extremely like that of the typical *Stromatoporæ*; but the horizontal laminæ and radial pillars are completely merged in one another, so as to be incapable of separation as distinct structures; though both of them exist in a modified form, and the interlaminar spaces are present as well. One of the forms belonging to this group is very common in the Clinton formation in North America, and often attains very considerable

dimensions, forming flattened elliptical masses from six inches to a foot in diameter; and the same form is found in the Niagara Limestone in Canada*. When superficially examined, this species is almost undistinguishable from *Stromatopora striatella*, D'Orb., which it closely resembles in the extreme closeness and density of its reticulate tissue. When examined, however, by means of thin vertical sections, this form is found to differ fundamentally from *S. striatella* in not consisting of distinct horizontal laminæ, separated by interspaces crossed by radial pillars. On the contrary, the entire structure is minutely vesicular, like a *Cystiphyllum*, but much more delicate, composed of innumerable oval vesicles placed in concentric lines, and very often opening into each other at both extremities. In other words, the horizontal laminæ are inflected so as to form a number of small oval cavities, which may or may not be separated from one another; and when these inflections are so pronounced as actually to separate contiguous laminæ, then they represent the "radial pillars" of the normal Stromatoporoids.

Another form belonging to this group is a large massive Stromatoporoid from the Corniferous Limestone of North America, of which we possess numerous well-preserved examples, all of which, however, are infiltrated with silica, the skeleton itself generally remaining calcareous. In this form the minute structure is essentially similar to that of the preceding, but on a comparatively gigantic scale. The entire mass is composed of oval or elongated cells with calcareous walls, generally about three to a line, placed in horizontal rows, and sometimes opening one into the other by wide apertures. Though the longitudinal apposition of the cells in concentric and parallel rows gives the appearance of there being distinct horizontal laminæ, each vesicle has its own proper walls as a rule, as is distinctly shown in many instances where two vesicles are placed end to end without their walls coalescing. The vesicles, however, may be regarded as produced by the rapid undulation and inflexion of the horizontal laminæ, the "radial pillars" not existing as distinct structures. Horizontal sections show a similar network of oval vesicles

* We have recently found a precisely similar form to be of quite common occurrence in the Wenlock Limestone of the West of England; and though we have not yet been able to make thin slices of this, we are led to think it possible that the form usually termed *Stromatopora striatella*, D'Orb., may really be none other than this.

with wide and open meshes. When examined with low powers, and especially with the use of polarized light, the walls of the vesicles sometimes exhibit the appearance of being traversed by numerous vertical tubuli, placing contiguous vesicles in successive layers in direct communication. This structure would be very closely similar to that of the Foraminiferal genus *Tinoporus*; but we cannot assert positively that it exists, though we have paid special attention to this point. The surfaces of the layers in this form, when exposed in weathered specimens, usually show nothing but the oval siliceous casts of the sarcode-chambers, separated by vermiculate and anastomosing depressions. These two forms appear to us to be so fundamentally distinct from *Stromatopora* proper, in spite of their close general resemblance to it, that we propose to give them a special name, viz. *Clathrodictyon*. We propose, further, to name the Clinton species *C. vesiculosum*, and the Corniferous form *C. cellulosum*.

(*d*) Lastly, we may note the occurrence of forms in most respects resembling the Stromatoporoids in appearance and general arrangement, but having merely a loosely reticulate and indefinite minute structure. The only specimen we have of this group is from the Cincinnati group (Lower Silurian) of Waynesville, Ohio, and is completely silicified, the skeleton being converted into flint, and the interspaces filled with transparent silica. In general form the fossil is Stromatoporoid, composed of concentric shells, and having an undulating surface, elevated into conical prominences. Internally the skeleton is irregularly reticulate and porous, traversed by canals which often radiate from minor centres. Our investigations of this specimen, though sufficient to indicate its distinctness as a separate type, have not been carried so far as to justify us in giving it a separate title. Forms of an apparently similar nature occur in the Corniferous Limestone (Devonian) of Ohio, but we have not hitherto been able to examine these minutely.

10. *Classification and Types of the Stromatoporoids.*—The Stromatoporoids have generally been grouped and classified in accordance with certain well-marked external features, such as the presence or absence of radiating horizontal water-canals, the presence of vertical tubes penetrating the mass, &c. These characters are sometimes sufficient (as in the case of the vertical canals of *Caunopora*); but more minute examination has shown that others, formerly relied upon as tests of generic distinction,

are common to forms which in intimate structure are very different. Thus the radiating surface-canals which induced Winchell to found the genus *Cœnostroma* are found in forms having the intimate structure of *Stromatopora*, in the utterly abnormal *Pachystroma*, and (in an especially well-marked form) in the group of Stromatoporoids designated by one of us *Syringostroma* (Nicholson, Pal. Ohio, vol. ii.). It appears, therefore, that we must fall back in classifying the Stromatoporoids upon their ultimate constitution as shown by the microscope, discarding such general features as the presence of radiating surface-grooves and water-canals, and relying solely upon the different modes of arrangement of the minute elements of the skeleton. In this case, such genera as *Cœnostroma*, Winchell, and *Syringostroma*, Nich., will have to be abandoned and redistributed, or possibly retained as subgenera. In the following pages we shall bring forward a provisional arrangement of the Stromatoporoids, based upon their minute structure, and excluding in the meanwhile all types which do not appear to us to be easily recognizable.

(*a*) Stromatopora, Goldfuss.

(Petrefacta Germaniæ, 1826.)

Skeleton ("sarcodeme") consisting of concentric calcareous laminæ, separated by distinct "interlaminar spaces," which are crossed by numerous vertical "radial pillars." In some cases there are radiating water-canals and surface-grooves placed round minor centres. Sometimes there are seen on the surface the openings of large water-canals ("oscula").

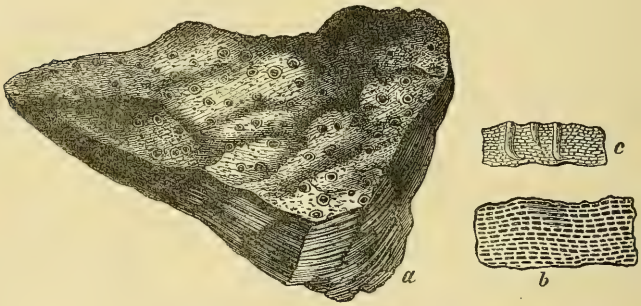
Habit.—Forming irregular masses, sometimes with a foreign body as a nucleus; spreading out into extended expansions, covered inferiorly by a thin striated calcareous membrane ("epitheca"), or growing in thin layers parasitically upon foreign objects.

Type.—*Stromatopora polymorpha*, Goldfuss.

We have not personally had the opportunity of examining specimens of *S. polymorpha*, but judging from the figures and descriptions of authors, and especially from those of Von Rosen, there can be no doubt that its minute structure is as indicated in the above definition. If this be the case, then *Stromatopora* proper will include all those Stromatoporoids in which the skeleton consists of concentrically disposed horizontal laminæ, the

interspaces between which are crossed with more or less regularity by well-developed and complete radial pillars, producing the tissue of regular quadrangular cells which forms such a characteristic feature in vertical sections of forms of this type. Among the forms which we have examined ourselves, we may mention as belonging to the same type—*S.* (*Cœnostroma*) *granulata*, Nich., *S. tuberculata*, Nich., *S. ostiolata*, Nich., *S. nulliporoides*, Nich., *S. nodulata*, Nich., and *S.* (*Cœnostroma*) *discoideum*, Lonsd. sp. It appears, also, that *S. typica*, Von Rosen, and *S. expansa*, Hall and Whitfield, should be placed here; and there are doubtless many other forms with whose internal structure we have but an imperfect acquaintance.

Fig. 4.



Stromatopora (*Caunopora*) *perforata*.

a. Fragment showing the osculiferous upper surface, of natural size. *b*. Vertical section exhibiting internal structure, magnified. *c*. Another vertical section, very slightly enlarged, showing more especially the perpendicular canal-structure. From the Corniferous limestone, Port Colborne, Ontario. (After Nicholson.)

While all the above agree in the peculiar form and arrangement of the minute elements of the skeleton, they present various differences in structure, some of which will probably be found to be of sufficient importance to serve as a basis for the establishment of subgenera.

S. polymorpha, Goldfuss, and *S. typica*, Von Rosen, exhibit very clearly two sets of pores, which penetrate the concentric laminæ and open on the surface. Most of these pores are very minute, and may perhaps be compared with the "inhalant apertures" or "pores" of Sponges; while others are much larger,

are often placed at special points, and may correspond with the "exhalant pores" or "oscula" of Sponges. Both also exhibit the radiating surface-grooves and canals which are present in the so-called *Cœnostromæ*. Similar radiating canals are present in *S.* (*Cœnostroma*) *discoidea*, Lonsd., *S. granulata*, Nich., and *S. tuberculata*, Nich., though in these instances they appear to be confined to the superficial layer, and to be mere subdermal grooves. In other cases no such structure can be detected. In *S. ostiolata*, Nich., there are well-developed and regularly disposed apertures of large size ("oscula"?). In some cases (e. g. *S. nodulata*, Nich., and *S. nulliporoides*, Nich.) the surface is smooth; but it is generally covered with miliary granules, tubercles, or vermicular ridges.

The *geological range* of *Stromatopora* proper, so far as our own personal observations go, is Upper Silurian and Devonian.

(*b*) Caunopora, Phillips.

('Palæozoic Fossils of Cornwall,' &c., 1841.)

Skeleton ("sarcodeme") massive or expanded, its general structure very similar to that of *Stromatopora* proper, but the concentric laminæ minutely undulated and inflected, and the radial pillars often more or less rudimentary (as in *Clathrodictyon*). The reticulated skeleton is perforated by large tubes half to one line in diameter), which have strong calcareous walls, are open throughout, or crossed by a few remote horizontal partitions, are sometimes connected with one another by lateral tubes, are in the main perpendicular to the concentric laminæ, and finally open on the surface in the form of large rounded apertures.

Type.—Caunopora placenta, Phill.

In this section we must also place *C.* (*Stromatopora*) *perforata*, Nich., from the Corniferous Limestone of North America. The chief point by which this type is distinguished from *Stromatopora* proper is the presence of vertical tubes, with definite walls, perforating the entire mass. As has been previously stated, the microscopic examination of the only Devonshire example of Phillips's *C. placenta* at our disposal does not allow us at present to accept Ferd. Roemer's suggestion that the genus is founded upon specimens of *Stromatopora* which have enveloped a coral *.

* As we have before remarked, we are now in possession of a fine series of specimens of *Caunopora* from the Devonian limestone of Devonshire, which seem to render it certain that the tubes of this form are really part and parcel of the Stromatoporoid itself, and that they are not due to the fact that the latter has simply enveloped a coral of the type of *Syringopora*.

The only coral which occurs in the same strata, and which presents any resemblance to the tubes of *Caunopora*, is *Syringopora*; and we most freely admit that there is a singular resemblance between the two. Microscopic sections of *Caunopora* show, however, that its tubes want all the characteristic internal structures of *Syringopora*; so that we must provisionally conclude that we have to deal here with a structure really belonging to the Stromatoporoid, and certainly sufficient to warrant its generic separation from *Stromatopora*.

The range of *Caunopora*, so far as we can speak ourselves, is exclusively Devonian.

(*c*) Clathrodictyon, Nich. & Murie.

Skeleton ("sarcodeme") massive, closely resembling *Stromatopora* in superficial aspect and general appearance and structure, but differing in the fact that the concentric laminæ are minutely undulated, and inflected at short intervals, so as to give rise to successive layers of oval or rounded cells or vesicles, which are usually distinct, but at other times open into one another by the imperfection of their lateral boundaries. There are thus no "radial pillars" as independent structures; but their place is taken by partial or complete inflexions of the horizontal laminæ bounding the interlaminar spaces, which are bent in such a way as to divide the space into complete or incomplete oval compartments. Horizontal section simply reticulate. Surface tuberculate.

Type.—*Clathrodictyon vesiculosum*, Nich. & Murie.

Geological Range.—Upper Silurian and Devonian.

[Though it is no part of the object of the present paper to enter into the characters of species, we may as well append here brief specific diagnoses of the only two forms of this group known to us, both of which are new.]

Clathrodictyon vesiculosum, Nich. & Murie.

Spec. char.—Skeleton in the form of cake-like expansions, from three inches to a foot in diameter, one to two inches in thickness centrally, but thinning out towards the circumference. Upper surface irregularly undulating, and exfoliating concentrically round the elevated points. Surface smooth. Internal structure of exceedingly fine and close-set horizontal or slightly undulating laminæ, of which about twenty or twenty-five occupy the space of one line (counting in the intervening interlaminar spaces as well). The interlaminar spaces divided into minute lenticular cells formed by curved inflexions of the horizontal laminæ.

The entire structure of the fossil, as viewed in vertical sections, resembles that of a *Cystiphyllum*; but the vesicles are so minute that in merely polished slices the hand-lens will hardly reveal any structure at all. In its general characters the fossil resembles that usually labelled *Stromatopora striatella*, D'Orb.; but it is densely and closely vesicular in structure, and the examination of thin sections with the microscope at once shows its entire distinctness from *Stromatopora* proper.

Form. & Loc.—Common in the Clinton formation of Yellow Springs, Ohio (infiltrated with dolomite); not so common in the Niagara Limestone of Thorold, Ontario. Upper Silurian. *Coll.* Nicholson.

CLATHRODICTYON CELLULOSUM, Nich. & Murie.

Spec. char.—Skeleton forming irregular masses or thick expansions, which attain a considerable size. Horizontal laminæ about four in the space of one line, inflected so as to form complete or incomplete partitions, which divide the interlaminar spaces into a number of irregularly oval vesicles, of which about three occupy the space of one line. Surface tuberculate or granulated, the tubercles apparently occasionally perforated.

This beautiful species was first discovered by our friend Mr. George Jennings Hinde, who at once recognized its distinctness from previously recorded forms, and pointed out the fact to one of the present writers. All the specimens which we have seen are either actually silicified, or are infiltrated with silica, the skeleton remaining in the latter case calcareous. In excessively thin vertical sections, the walls of the vesicles of the mass, in parts, present the appearance of being perforated by minute tubuli; but we have been unable to satisfy ourselves of the reality of this appearance, though, if established, this would throw an important light upon some questions as to the minute structure of the Stromatoporoids.

Form. & Loc.—Common in the Corniferous Limestone (Devonian) of Wainfleet, Ontario. *Coll.* Hinde and Nicholson.

(*d*) STYLODICTYON, Nich. & Murie.

Skeleton composed of laminæ and interlaminar spaces, the latter crossed by radial pillars. The entire mass is supported upon a system of vertical columns, which may be composed of comparatively dense calcareous tissue, or may, in other cases, be loosely reticulated, and which are occasionally occupied by vertical canals. Round these vertical columns the horizontal laminæ and interspaces are concentrically arranged in successive layers; and the more or less extensive spaces between these are filled up with reticulated tissue disposed in horizontal layers or irregularly. Radiating water-canals may or may not be present.

Type.—Stylodictyon (*Syringostroma*) *columnare*, Nich.

In the type species (Pal. Ohio, vol. ii. p. 253) the vertical pillars which traverse the mass are seen in transverse sections to be solid, and to be composed throughout of granular carbonate of lime. The chambers are arranged concentrically round the pillars; and there is an extremely well-developed system of water-canals arranged in radiating groups, the cut ends of these appearing conspicuously in vertical sections as so many large rounded apertures. The range of *Stylodictyon*, so far as we know, does not extend beyond the Devonian. We append a short definition of *S. retiforme*, the only other type of this group with which we are acquainted.

Stylodictyon retiforme, Nich. & Murie.

Skeleton massive, composed of vertical columns, surrounded concentrically by laminæ, the interlaminar spaces being crossed by delicate vertical or "radial" pillars. The columns themselves are made up of reticulated calcareous tissue, sometimes with a central vacant space or canal; and their diameter (including that of the concentrically-disposed vesicular tissue round each) varies from one to two lines. They are placed about their own diameter apart; and the interspaces between them are filled with loosely reticulated tissue. No radiating water-canals are present.

This species was collected by Mr. George Jennings Hinde, who recognized its novelty, and kindly furnished us with specimens. It is at once distinguished from *S. columnare* by the reticulated nature of the columns which intersect the mass, and by the absence of radiating canals, as well as by other points which we need not notice here.

Form. & Loc.—Hamilton Formation, Rivière aux Sables, Ontario, rare. *Coll.* Hinde and Nicholson.

(*e*) Stromatocerium, Hall (emended).
(Pal. N. Y. vol. i. p. 48.)

Skeleton ("sarcodeme") massive, composed of dense and thick calcareous horizontal and concentric laminæ, separated by very narrow and irregular interspaces. The horizontal laminæ are not continuous, but are irregularly disposed; there are no "radial pillars" crossing the interlaminar spaces; and the entire mass is perforated by vertical tubes, which have no walls, are much smaller than the tubes of *Caunopora*, and are placed at short but irregular distances apart. These tubes place the successive interlaminar spaces in communication; and though they often run through many interspaces successively, they cannot be said to be continuous from the top to the bottom of the mass. Surface unknown.

Type.—Stromatocerium canadense, Nich. & Murie.

As previously stated, we have restored Hall's genus *Stromatocerium* for the reception of a Stromatoporoid from the Trenton Limestone of Canada (Lower Silurian), which we have reason to think to be allied to Hall's *Stromatocerium rugosum*, or possibly even identical with it. The species just referred to, however, was very imperfectly defined; and the genus was not characterized in any recognizable manner. There is, however, no doubt that the form figured and described by Hall is a true Stromatoporoid; and as we know of no other members of this group at this horizon, we have thought it best to restore Hall's genus, rather than to create a new one, though our type is so clearly distinct from all the other Stromatoporoids that we should have been quite justified in giving it a fresh generic designation. As Hall's species, however, cannot be recognized, we shall provisionally describe our form under the name of *S. canadense*.

STROMATOCERIUM CANADENSE, Nich. & Murie.

Spec. char.—Skeleton having the form of large rounded or irregular masses, conspicuously composed of numerous dense concentric laminæ, about five of which (with the intervening interlaminar spaces) occupy one line. The interlaminar spaces are open, without radial pillars; and the mass is traversed by numerous discontinuous vertical canals, from $\frac{1}{50}$ to $\frac{1}{80}$ inch, or less, in diameter. Surface-characters unknown.

Form. & Loc.—Trenton Limestone (Lower Silurian), Lake Couchiching and Peterborough, Ontario. *Coll.* Nicholson.

(*f*) PACHYSTROMA, Nich. & Murie.

Skeleton massive, composed of numerous concentric calcareous laminæ of extraordinary thickness, which are either in contact with one another or are separated by narrow and irregular interspaces. When interlaminar spaces exist, they are open, and there are no "radial pillars." The great concentric laminæ are composed of dense and indefinitely, but very minutely, porous and reticulate calcareous tissue, having no regular arrangement, but perforated by numerous very minute, irregular, vertical vermiculate tubes, without distinct walls. Horizontal radiating groups of water-canals are present. Surface smooth.

Type.—Pachystroma antiqua, Nich. & Murie.

The type species of this singular genus is from the Upper Silurian (Niagara Limestone) of Canada; but we must also refer here the *P.* (*Syringostroma*) *densa*, Nich., of the Devonian of Ohio. In this latter form (Pal. Ohio, vol. ii. p. 251) the radiating

water-canals are of comparatively large size, and their apertures are conspicuously visible in vertical sections. We subjoin a brief diagnosis of the type species.

PACHYSTROMA ANTIQUA, Nich. & Murie.

Sarcodeme massive, subspherical, of thick concentric laminæ, which have the extraordinary thickness of from three quarters of a line to two lines. Interlaminar spaces wanting or irregular. Even when there are no interlaminar spaces, however, the separate laminæ are always marked by a distinct interval, which marks a stage of growth, and which if followed laterally is found to expand into irregular interspaces. Surface with delicate branching canals arranged in stellate systems. Internal structure of laminæ minutely porous and reticulate, especially towards their central parts, with delicate vertical tubes at intervals.

Form. & Loc.—Niagara Limestone, Thorold, Ontario. *Coll.* Nicholson.

(*g*) DICTYOSTROMA, Nich.

(Pal. Ohio, vol. ii. p. 254.)

Sarcodeme massive, composed of thick solid calcareous concentric laminæ, apparently traversed by horizontal canals, and separated by wide interlaminar spaces. Upper surfaces of the laminæ sending off strong calcareous processes, which represent the "radial pillars," but seem not to be directly connected with more than the lamina from which they spring.

Type.—Dictyostroma undulata, Nich. This form resembles *Stromatopora* proper in general structure, except that the laminæ and interlaminar spaces are of comparatively gigantic size. We have had no opportunity of examining its minute structure; and therefore the group cannot be properly characterized.

The type species of this group is from the Niagara formation (Upper Silurian) of Kentucky; and we know of no other form at present.

AFFINITIES AND SYSTEMATIC POSITION OF THE STROMATOPOROIDS.

That the fossils under the so-called *Stromatopora* include a number of forms at first difficult to collate, has been admitted by most authorities who have investigated the group. As we have shown, certain specimens which, from their general aspect, the localities where obtained, and other reasons, must, for the present at least, be deemed Stromatoporoids, are nevertheless so aberrant, and sometimes so altered in condition and minute structure, as to leave a loop-hole of doubt concerning their nature. Dismissing

at this juncture such variations and gradations, the more typical forms at all events are indubitably marine organisms often associated with Coral formations, in the concretionary mass and débris of which occasionally shells, encrinites, and various other foreign bodies are mixed. Their main characteristics are:—Masses laminar, in thicker or thinner layers, concentrically arranged and mostly fastened to a foreign body; surface with or without elevations, and usually though not always exterior orifices of two kinds; in some instances channels perforate the substance; the latter composed of a series of laminæ so disposed as to enclose cellular interspaces, rectangular, retiform or otherwise; stellate surface-tracery and an epitheca are occasionally present.

In discussing the question as to the affinities and systematic position of the Stromatoporoids, probably the best course to pursue will be to review briefly the chief arguments for and against their allocation to the several zoological groups in which they have been placed by different observers—the groups in question being the Corals, the Hydrozoa, the Foraminifera, the Sponges, and the Polyzoa,—previous to which we will advert to certain marine Plants, viz. the Corallines.

1. *To Nullipores.*—Although so far as we are aware no one has suggested *Stromatopora* to have a vegetable alliance, nevertheless there is in some respects a wonderful resemblance to certain of the Nullipores.

Thus many of these Lithophytes or Stone Plants simulate the characters of *Stromatopora*, inasmuch as they are calcareous in substance, spread or insinuate themselves in thin layers parasitically between corals and other foreign bodies, occasionally form denser incrusting masses, have a nodular and granulated surface, invest and cover objects in successive layers, and in their minute structure present extreme regularity, with a tendency to quadrangular cell-construction. While these remarks apply in a general way, it by no means follows that the fossil *Stromatoporæ* belong to the group in question; on the contrary the bulk of evidence goes to support the view that their skeleton is the product of animal organization.

Setting aside the leafy jointed Corallines as at a glance outwardly distinctive in form, habit, &c., we were fortunate in obtaining some large pieces of Nullipores from South Africa (species undetermined) for comparison. These Nullipores were, roughly speaking, of two kinds, viz. a few large crustaceous forms, and others of a short, compact, branching, or interwoven sort.

The former, crust-like expansions, had an undulating mamillated contour, and in part a granular superficies. The nodular and nipple-shaped elevations also sparsely showed apical perforations; and here and there the broken surface demonstrated a tendency to scaly layers. Thus, what with the dirty brownish-white colour of the specimens, and other visual characters, there was indeed great likeness to some specimens of *Stromatopora*. The other, densely interwoven, branching Nullipores in their general configuration and chalky colour more markedly differed from the ordinary Stromatoporoid appearance.

In both series of Nullipores, however, in this mere casual outward examination, it was interesting to note how in the weathered areas and undulating exposed layers the calcareous films and subjacent often reticular substance evinced a similar disposition to put on the Stromatoporoid facies. Another feature more manifest in some than in others of the specimens was the presence of larger tortuous and other perforations of a boring parasite, besides undoubted tortuous *Serpula*-tubes, and foreign substances intermixed in the crevices. In none of these specimens did any of the fresh or weathered sections offer the special feature of *Stromatopora*, viz. distinctly perceptible interlaminar spaces and vertical radial pillars; though, as aforesaid, in weathered superficial layers minutely cribriform structure occasionally prevailed. Instead, throughout the mass as a rule the dense chalky consistence appeared to the eye or through the hand-lens. Stellæ or radiate water-canals are entirely absent both superficially and deeply.

As regards their intimate and minute structure, microscopical sections, made in various directions and from each and all of the specimens, only confirmed what is already well known concerning the histology of the Corallinaceæ. Their distinctive vegetable cells, far more minute than any of the so-called sarcode-chambers of the Stromatoporæ, perfectly agreed in every detail with those of the Corallineæ and Nulliporæ of our own coasts—to wit, such forms as *Corallina officinalis*, *C. incrassata*, *Melobesia polymorpha*, and *M. pustulata*, &c.

Thus, taken as a whole, the Nullipores do not possess Stromatoporoid essentials; and what resemblances exist between them are rather a combination of superficial characters than those of close or true affinity. The study and comparison of these South-African Nullipores, among other things, carries with it this useful lesson—that these calcareous bodies are subject to extraneous in-

fluences for the production of most if not all of their canalicular, and what may be termed poriferous aspects. The similitude to what is extant in certain of the Stromatoporoids in this connexion suggests caution in the interpretation of these structures in the latter.

2. *To Foraminifera.*—We may next briefly consider the chief facts bearing upon the relationship of the Stromatoporoids to the Foraminifera—a relationship which has been frequently suggested, and which has been more especially insisted on by Principal Dawson ('Dawn of Life,' p. 156 *et seq.*)

As this distinguished observer, we believe, is about to publish in full the results of his investigations into this subject, we shall merely make a few brief remarks on the question, the more so as we have already (see pp. 193 & 195) referred to Dr. Dawson's views so far as published. If we compare such a Stromatoporoid as those which we have described under the name of *Clathrodictyon* with such a Foraminifer as *Tinoporus*, there is no doubt as to the striking general similarity in minute structure; but this similarity becomes much reduced if we take for the purpose of this comparison the more regular and typical forms constituting *Stromatopora* proper. In thin sections of *Clathrodictyon cellulosum*, Nich. & Murie, we have thought that we have been able to make out minute microscopic tubuli, placed side by side, and uniting neighbouring compartments of the fossil directly with one another. If we could have established this point (and we have seen similar appearances in some other forms), then we might have instituted a direct and close comparison between *Clathrodictyon* and *Tinoporus*. Unfortunately, we have not been able to satisfy ourselves thoroughly that these apparent tubuli have any actual existence even in the forms above alluded to; whilst in the great majority of forms we have failed to detect any traces of similar structures. So far as our present observations go, therefore, we are unable to assert positively that the skeleton of the Stromatoporoids is perforated by any system of *microscopic tubuli*, similar to the tubuli found in the test of the Perforate Foraminifera; and we do not, therefore, feel ourselves justified in considering that there is any direct affinity subsisting between the two groups of organisms.

Exception, however, may be made to *Loftusia* and *Parkeria*. Amongst the undoubted fossil Foraminifera, the nearest ally of the Stromatoporoids is probably to be found in the gigantic arenaceous Foraminifers of the Greensand described by Dr. Carpenter

under the name of *Parkeria*, in an exhaustive and fully illustrated monograph (Phil. Trans. vol. clix. p. 721). Dr. Carpenter suggested to us in our present inquiry that we should find *Parkeria* to be related to the Stromatoporoids; and he kindly placed at our disposal a number of his microscopic preparations of the former. We have also carefully examined specimens of *Parkeria* by means of sections prepared by ourselves. *Parkeria*, as is well known, occurs in the form of globular bodies from about half an inch up to two inches or more in diameter. When these spheres are laid open, they are seen to be "formed of a series of concentric *lamellæ* of 'labyrinthic structure,' partially separated by concentrically disposed *interspaces*, but connected at intervals by 'radial processes,' which consist of large tubes that are surrounded (in all except the five or six innermost layers) by labyrinthic structure resembling that of the concentric lamellæ." The entire skeleton is made up of minute sand-grains and granules of phosphate of lime cemented together by a cement of carbonate of lime. In the fact that both *Parkeria* and the typical Stromatoporoids are composed of concentric laminæ, with interlaminar spaces and radial pillars, there is a striking resemblance established, enough to warrant the supposition that both might belong to the same systematic group. The *general* resemblance of structure thus indicated is even further increased when we compare with non-infiltrated specimens of *Parkeria* the decalcified casts in silica of the sarcode-chambers of a typical Stromatoporoid. We have, however, satisfied ourselves that no real relationship of affinity exists between *Parkeria* and *Stromatopora*; and the principal grounds upon which this conclusion is based are the following:—

(*a*) *Parkeria* possesses a skeleton essentially identical with that of the "arenaceous" Foraminifera generally, consisting, namely, of distinct grains of sand and phosphate of lime cemented together. *Stromatopora* and its allies, on the other hand, possess a *calcareous* skeleton, as we have formerly shown; and in no case can it be shown to be composed of definite and distinct *grains* of any mineral substance.

(*b*) All the parts of the skeleton of *Parkeria* have that complex construction out of minute irregular chambers, to which Dr. Carpenter applied the epithet "labyrinthic." On the other hand, the concentric laminæ and radial pillars of the Stromatoporoids do not exhibit any labyrinthic structure, though occasion-

ally porous. Even the huge lamellæ of *Pachystroma*, each of which probably represents several amalgamated lamellæ with their intervening interspaces in the ordinary Stromatoporoids, cannot be properly said to be "labyrinthic."

(*c*) The "radial" pillars of *Parkeria* are perforated by large canals. This is not the case, as a rule at any rate, with the Stromatoporoids, whilst there are forms amongst the latter in which the radial pillars are entirely wanting.

(*d*) In their general form and habit, the Stromatoporoids differ widely from *Parkeria*, the latter being free, whilst the former were attached to foreign bodies and sometimes incrusting or parasitic.

(*e*) Nothing comparable with the nucleus of *Parkeria** can be detected in any Stromatoporoid.

3. *To Sponges.*—According to Von Rosen the fossil form *Sparsispongia*, D'Orb., is really referable to the Stromatoporoids. If such is proved to be the case, it would seem not unlikely that the secondary genus *Stellispongia*, D'Orb., may really belong to the same group. But as we have had no opportunity of examining specimens of either of the above minutely and critically, for the time being we must leave the question open. The same may be said of certain other forms—to wit, *Spongia stellata*, Lamx., and specimens designated in our museums *Sphærospongia*.

It certainly is to the Sponges, more frequently than to any other group, that the Stromatoporoids have been referred by previous observers, including one of the present writers; and they have been placed, collectively or as regards individual form, in the groups of the Horny, the Siliceous, and the Calcareous sponges. On the whole subject of the relationship between the Stromatoporoids and the Sponges, we shall content ourselves with adducing the following considerations:—

First, the reference of the Stromatoporoids to the *Horny* Sponges, chiefly supported by the authority of Von Rosen, we believe to be entirely inadmissible; and, without entering into the question in detail, we may simply state that this conclusion was essentially based on the assumed fact that the Siliceous Sponges of the Chalk, since undoubtedly proved to possess a

* Our friend Dr. John Millar has enabled us to examine a series of most excellent specimens illustrating the structure of *Loftusia* and *Parkeria*. Two distinctive kinds of *Parkeria*, both in considerable abundance, have been got by him from the Cambridge beds. He is inclined to regard *Parkeria* as evincing affinities with the Polyzoa rather than strictly with the Foraminifera; but as his researches are still in progress we must defer further notice.

flinty skeleton, were really horny. Nor have our own researches upon the minute structure of the Stromatoporoids at all served to corroborate Von Rosen's view—that these organisms are composed of any thing to which the name of "*fibres*" could be properly applied.

Secondly, the principal observer who of late years has taken the view that the Stromatoporoids are Siliceous Sponges is Mr. Sollas (Ann. & Mag. Nat. Hist. ser. 4, vol. xix. p. 23), who places *Stromatopora concentrica* among the *Vitreohexactinellidæ*. Mr. Sollas, however, has subsequently (Quart. Journ. Geol. Soc. vol. xxxiii. p. 824) stated that he only believes some of the Stromatoporoids to be of this nature, and that others fall into different groups. As Mr. Sollas has not yet published any of the evidence upon which his views are based, it is, of course, impossible for us to express any opinion in the matter. Two observations only appear to be justifiable:—in the first place, that much will depend upon the question whether the form which Mr. Sollas calls *S. concentrica* (and which, if it be the *S. concentrica* of Goldfuss, is really identical with *S. polymorpha*, Goldf.) be truly referable to *Stromatopora* itself; and, secondly, that all the evidence derivable from the very extensive series of forms which have passed under our hands is, as we have previously stated at greater length, to our minds absolutely conclusive as to the original calcareous constitution of the Stromatoporoids. We should add, however, that we have not had the opportunity of examining personally the original types of *Stromatopora concentrica*, Goldf. (=*S. polymorpha*, Goldfuss), and have only had the opportunity of studying it by means of the excellent figures and descriptions of Von Rosen and Goldfuss. It is *possible*, therefore, that *this* form, the type of *Stromatopora* itself, will prove to be a Hexactinellid Sponge. In that case, however, we should simply have to withdraw all the forms which we have been considering in this memoir under the name of "Stromatoporoids," from any association with *S. polymorpha*, Goldf.; for we are quite satisfied that, whatever the true nature of *these* may be, they are not *Hexactinellidæ* *.

* Since our MS. has been lying in the printers' hands, one of us (H. A. Nicholson) has visited the Eifel, and has both collected a large series of Stromatoporoids from this classical district and examined those in the Bonn Museum. The result of this has been to satisfy us that the Stromatoporoids of the "Eifler-Kalk" are in no respect fundamentally different from those of the Devonian of Devonshire and North America. Further remarks on this head must be left to another opportunity.

In the third place, there remain for us to consider the possible relations between the Stromatoporoids and the Calcispongiæ. In this connexion we may first note the remarkable resemblances between the Sponges and the Stromatoporoids as regards their general form, their ordinary modes of growth (as evinced by some forms, though not all), and the principal characters presented to the unassisted eye by the free surfaces of each. We may next note the resemblance between these two groups, constituted by the presence in many Stromatoporoids (and perhaps in all) of two sets of apertures in the superficial layer, and two sets of canals perforating the skeleton. When we add that the apertures of the larger canals in some forms are placed at the summit of conical eminences, and that they may be disposed with some regularity, we have said enough to show how striking is the general resemblance between these two sets of openings in the Stromatoporoids and the "pores" and "oscula" of the Sponges. On the other hand, to resemblances like the above, which have so strongly impressed many observers, we have to oppose some serious and important points of dissimilarity. By far the most important of these is to be found in the nature of the skeleton. In all the known Calcispongiæ, the skeleton consists of free *spicules*, which are never amalgamated or fused with one another, and which, therefore, never form a continuous framework, however densely they may be packed together. In no Stromatoporoid, however, have free calcareous spicules ever been detected by any observer; and the skeleton is undoubtedly a more or less continuous one. If, therefore, we were to accept the view that the Stromatoporoidea were really referable to the Calcareous Sponges, we should have to assume that they constitute a special, peculiar group, bearing a relation to the typical Calcispongiæ somewhat similar to that which the Lithistidæ or Hexactinellidæ of the present day bear to those Siliceous Sponges in which the spicules are not united or soldered together (Sarcohexactinellida of Carter, the Lyssakina of Zittel). Nor can any serious *à priori* objection be brought against this view, since there is no fundamental reason why there should not be a group of Calcispongiæ with free spicules, and another group of the same with a vermiculate or reticulate continuous skeleton, just as we know that in nature there are found parallel groups amongst the Siliceous Sponges.

But withal there is still the further trenchant difficulty to be

surmounted—viz., that to substantiate the latter view it is necessary to assume as a fact a form of Sponge to the existence of which living representatives do not yield evidence of an unquestionable kind. This doubtless weakens the argument very considerably, however much the construction of the *Stromatoporæ* is spongiose in character. Nevertheless difficulties of a kindred nature, and quite as insurmountable, are to be met with, to whatever living group they may be compared.

4. *To Corals &c.*—The Stromatoporoids have been regarded by various observers as referable to the Actinozoa; and they have been placed, collectively or severally, amongst the Tabulate Corals, the Alcyonaria, and the Perforate Corals. As to their relationship with the Tabulate Corals (such as *Fistulipora*), or with the Alcyonarians (such as *Tubipora*), it may be at once stated that their minute structure, as displayed by means of thin sections, is conclusive against their reference to either of these groups, and shows, indeed, that their true nature is entirely different. For the view that they belong to the *Zoantharia perforata* more may be said. There is undoubtedly a close general resemblance between some of the Stromatoporoids, such as *S. discoidea*, Lonsd., and *S. granulata*, Nich., and some of the Perforate Corals, such as *Psammocora* and *Montipora* and other members of the Poritidæ—this resemblance depending partly upon the general similarity of the reticulate calcareous skeleton of both, and partly upon the likeness of the water-canals of the former to the corallites of the latter. When closely examined, however, this likeness is seen to be clearly superficial, and not fundamental. The minute structure of the general skeleton of the Stromatoporoids differs materially from that of the Perforate Corals in its arrangement; while the stellate systems of water-canals in the former, which simulate corallites, are really of a totally different nature, and are, under any circumstances, totally wanting in many Stromatoporoids. We may, therefore, unhesitatingly dismiss the view that the Stromatoporoids are to be referred to the Corals properly so-called.

Lastly, we may compare the Stromatoporoids, briefly, with the Carboniferous fossils which constitute the genus *Palæacis*, Haime, which have recently been carefully examined by one of us along with Mr. R. Etheridge, jun., F.G.S. The species of *Palæacis* are either free or attached to foreign bodies; and they differ from all the Stromatoporoids in the conspicuous presence of a variable

number of deep cups, which (on the view that *Palæacis* is a Coral) have been generally regarded as "calices." In their internal structure all the specimens of *Palæacis* are shown by microscopic examination to be composed of a reticulated calcareous tissue, which presents a close general resemblance to that of certain of the Stromatoporoids, while the surface is covered with tubercles and vermiculate ridges very similar to those exhibited by such forms as *Stromatopora tuberculata*, Nich., *S. discoidea*, Lonsd., &c. On the other hand, the reticulated tissue of *Palæacis* is not in any way divisible into concentric and radial elements, but is invariably irregularly and indefinitely trabecular, and the entire substance of the skeleton appears to be more or less conspicuously traversed by minute branching microscopic tubuli. There would not appear, therefore, to be any very close relationship between *Palæacis* and *Stromatopora*.

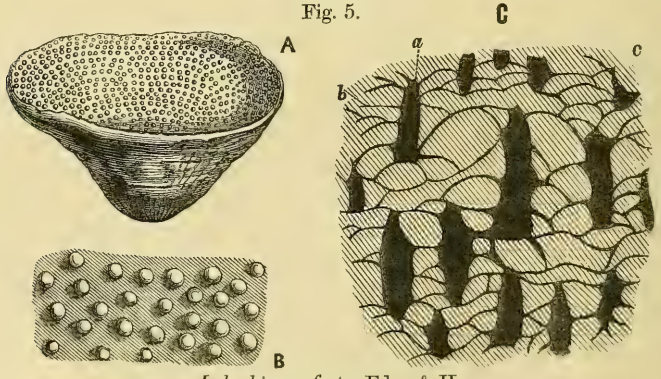
5. *To Hydrozoa.*—With regard to the reference of the Stromatoporoids to the Hydrozoa, we have to consider on the one hand their relationships to forms like *Millepora*, and on the other hand their affinities with *Hydractinia*. The likeness of certain of the Stromatoporoids to *Millepora* is very striking, but cannot be said to be sustained by a close examination, the arguments on this head being very much the same as those above referred to in connexion with the "Madreporaria perforata." Though *generally* like one another, no Stromatoporoid can be shown to consist of two definite systems of larger and smaller tubes, both divided by tabulæ; and none can be shown to possess a definite system of tubular cavities which can be supposed to have been tenanted by zooids, while many are destitute of even a semblance of structures of this nature. The only Stromatoporoids which would afford a reasonable basis for a comparison with *Millepora*, or with any of the so-called "Tabulate Corals," are those which form the genus *Caunopora*. If the structure of these has been rightly interpreted by us, and if the large vertical tubes of *Caunopora* really belong to the organism of which they seem to form a part, then we certainly have here a Stromatoporoid which may very fairly be compared with *Millepora*, or, indeed, with any of the so-called "Tabulate Corals." *Caunopora*, however, if its structure be rightly interpreted, is an aberrant form, and it cannot by itself decide the systematic position of the Stromatoporoids generally.

In 1876, Dr. Gustav Lindström (Ann. & Mag. Nat. Hist. ser. 4, vol. xviii. p. 4), in a paper on the "Anthozoa Tabulata," pointed out that the well-known Silurian fossil referred by Milne-Edwards

and Haime to the Tabulate Corals, under the name of *Labechia*, was rather related to the *Hydrozoa*. "In its earliest stages of growth, this fossil consists of a very thin circular disk, with concentric lines of growth beneath, and having the superior surface studded with blunt spines, which radiate from the centre, and also coalesce and form continuous ridges. In this state it reminds one of nothing more than the sclerobasis of the Hydrozoan genus *Hydractinia*; and the only difference seems to be that *Labechia* is entirely calcareous, whilst *Hydractinia* is corneous. During the course of growth, the primitive disk of *Labechia* is increased in thickness by the addition of successive thin strata, which closely conform to the subjacent fundamental crust, being elevated where the spines are situated. As these successive layers leave a small space between them, and are in themselves very thin, they give rise to a false appearance of tabulæ." (Lindström, *loc. cit.*) Dr. Lindström further points out that there are points of resemblance between *Labechia* and the Stromatoporoids which have been generally grouped together under the name of *Cœnostroma*; and he therefore throws out the suggestion that the latter may possibly have to be eliminated from the group of the Corals to which he thought them to belong.

Having carefully examined specimens of *Labechia*, both macroscopically and microscopically, we can entirely confirm Dr. Lindström's general description of the genus; and we altogether agree with him, that it certainly can not be referred to the Corals. Thin vertical sections (fig. 5, C) show that the skeleton is com-

Fig. 5.



Labechia conferta, Edw. & H.

A. A small specimen, of the natural size. B. A piece of the upper surface of the same, enlarged. C. Portion of a vertical section under a low microscopic power: *a*, the calcareous columns, represented as opaque; *b*, the vesicular tabulæ; *c*, calcite filling the lenticular vesicles.

posed of a series of short, discontinuous, fusiform, calcareous columns (*a*), which are about half a line in width, and are placed about half a line to a line apart. The spaces between these columns are occupied by curved calcareous lamellæ (*b*), which form a series of comparatively large lenticular vesicles (*c*). The upper surface is formed by the upper surfaces of these calcareous lamellæ, and by the prominently protruded free ends of the columns. The columns are wholly solid and imperforate, as are the lamellæ of the vesicular tissue. The vesicles of the latter, therefore, appear to be entirely destitute of any intercommunication, and we have failed to detect any openings or pores of any kind on the upper surface. The lower surface is likewise imperforate, and is covered by a concentrically striated calcareous membrane or "epitheca," which envelops all the inferior surface, except the comparatively small peduncle by which the colony is attached to foreign bodies.

That there is some resemblance between *Labechia* and some of the coarsely tuberculated species of *Stromatopora* is undeniable; but it appears to us to be a superficial likeness, and we are not prepared at present to offer a decided opinion as to the affinities of the former. That *Labechia* has also a *general* resemblance to the crusts of *Hydractinia* is also undeniable, especially now that Mr. Carter has described calcareous species of the latter genus (Ann. & Mag. Nat. Hist. ser. 4, vol. xix. 1877); but there are the following very important points to notice in this connexion. The colonies of *Labechia* are not *incrusting*, as are those of *Hydractinia*, but form expansions, resembling those of many corals, attached to a foreign body at one point, but having the greater portion of the inferior surface free and covered by a concentrically striated "epitheca." The columns of *Labechia* are invariably solid throughout, whereas the spines of *Hydractinia* are more or less reticulated basally, or traversed by a central canal. Lastly, the upper surface of *Labechia* has not yet been shown to present any apertures or crypts, such as may be supposed to have given exit to *zooids* of any description.

Recently Mr. Carter has thrown out the suggestion, and has strongly supported the view, that *Stromatopora* is truly very closely related to *Hydractinia*. We have very carefully studied the two memoirs which Mr. Carter has published bearing upon this subject (see Ann. & Mag. Nat. Hist. ser. 4, vol. xix. p. 44, 1877, and *ibid.* ser. 4, vol. xi. p. 1, 1873), and we have also spe-

cially examined our numerous thin sections of various Stromatoporoids, with a view of collecting all the evidence which these might offer in support or disproof of this view. Not having had the opportunity of thoroughly examining any *calcareous* species of *Hydractinia*, we should feel it presumptuous to express a final opinion on this question; but we submit the following considerations as, in our judgment, warranting the belief that at present there is insufficient evidence to connect the Stromatoporoids with *Hydractinia*, though such a connexion may subsequently be established.

First. As to general form and habit, few Stromatoporoids could be properly said to be *incrusting*, as compared with a *Hydractinia*, since they very rarely form *thin* crusts attached by the whole of the lower surface to foreign bodies. On the contrary, they either form massive aggregates, like those of many Corals, which may be attached by one point to a foreign body, or may have grown round such as a nucleus; or, in many cases, they form extended expansions, quite like those of many Corals (such as species of *Fistulipora*, *Favosites*, &c.), attached by a comparatively limited point to some foreign object, and having almost the whole of the lower surface *free* and covered with a well-developed calcareous striated membrane or "epitheca."

Secondly. The resemblance between the minute structure of the crust of *Hydractinia* and that of the typical Stromatoporoids is, in our opinion, a purely general one, and is not nearly so close as the resemblance between the Stromatoporoids and certain of the perforate Corals or such Hydrozoans as *Millepora*. This is particularly well seen by a comparison of magnified thin vertical sections of examples of these different groups.

Thirdly. The resemblance of the tuberculated superficial layer of certain Stromatoporoids to the upper surface of the crust of *Hydractinia* is also, in our opinion, a superficial one; whilst many Stromatoporoids, precisely agreeing with the former in minute structure and in the general arrangement of their parts, have perfectly smooth surfaces.

Fourthly. Many Stromatoporoids show very unmistakably two sets of apertures, one large and the other small, upon the surface, the large openings being often placed upon the end of rounded or conical eminences, and being often extremely regular in their arrangement. These phenomena cannot be paralleled by any thing exhibited by *Hydractinia*, so far as we are aware.

Fifthly. The stellate systems of water-canals, so commonly, though not universally, present in the Stromatoporoids, are apparently believed by Mr. Carter to correspond with the branched grooves and cœnosarcal stolon-like tubulation which he has described as characterizing the surfaces of the layers of the crusts of *Hydractinia.* We are unable to accept this view, upon the ground that the radiating water-canals of the Stromatoporoids, though sometimes superficial, especially where arranged round a superficial eminence, more commonly pass obliquely through the successive laminæ and interlaminar spaces, perforating these, as several of our preparations show, one after the other, and not lying in the plane of any particular lamina.

Sixthly. One of the Stromatoporoids which Mr. Carter has examined (Ann. & Mag. Nat. Hist. ser. 4, vol. xix. pl. viii. figs. 22, 23), and from which he has drawn important conclusions supporting his views, appears to us to be a member of the aberrant and still imperfectly understood genus *Caunopora**, or, if not so, to be a specimen in which a colony of *Stromatopora* has grown round and enveloped a colony of the coral *Syringopora.*

6. *To Polyzoa.*—We have already intimated (*antea*, p. 190) that the idea of the affiliation of *Stromatopora* to the Polyzoa is not new, since the two Sandbergers and Ferd. Roemer (1850–1856), for the reasons heretofore given, held this view. Apart from their interpretation of the structural resemblances, we have brought to bear examinations and comparisons on our own behalf. Among an extensive series of recent and fossil Polyzoan forms investigated by us with reference to the question at issue, we have been particularly struck by a good example of *Eschara nobilis,* Michelin. This specimen, from the Upper Greensand, was an ovoid mass several inches in diameter, externally irregular, roughened, and scaly, but with no elevations, perforations, or otherwise special outward resemblance to the Stromatoporoids. A vertical section through its middle displayed a small foreign body as a nucleus, around which, like the coats of an onion, in regular successive layers, about six to a line in depth, the tiers of zooidal cells were ranged. Thus this vertical section—what with the walls of the zoœcia so built up as to represent horizontal or concentric laminæ and vertical or radial pillars, the cells themselves resem-

* Quite recently, while this is passing through the press, Mr. Carter himself announces his mistake and admits his supposed *Stromatopora* to have been *Caunopora placenta* (Ann. & Mag. Nat. Hist., July 1878).

bling interlaminar spaces, and, moreover, the fossilized calcareous nature of the whole—undoubtedly simulated in a forcible manner the characters of *Stromatopora* in vertical section. This will readily be allowed if fig. 13, Pl. IV., be compared with fig. 3, Pl. I. If, again, the surface of one of the layers of *Eschara nobilis*, fig. 12, Pl. IV., be compared with the surface of the concentric laminæ of *Stromatopora tuberculata*, fig. 2, Pl. I., less likeness is discernible, though the weathered protruding pillars and pseudo-orifices of the latter may at first sight be taken for the cell-orifices of the former.

Closer inspection, however, does not bear out such apparent agreement; for the regularity in shape and position of the cells and orifices of the polyzoarium of this species of *Eschara* (*Hemeschara*, Busk), avicularia, and other secondary features are completely at variance with the structural surface-peculiarities of *S. tuberculata* and all other species of the genus. But even the general similarity of facies of vertical sections between the two forms in question diminishes in proportion as detailed and microscopic investigation is pursued; and from such Stromatoporoid genera as *Caunopora*, *Stylodictyon*, &c., the polyzoarium of *Eschara* departs still further. Another genus of the family of Escharidæ, namely *Retepora*, occasionally, to a certain extent, simulates the minute vesicular structure of *Clathrodictyon*; but the general fenestrated foliaceous nature of its polyzoarium, presence of avicularia, marginal spines, ovicells, &c., sufficiently distinguish Polyzooid from Stromatoporoid organization. Among the family of Celleporidæ again, in certain of its forms, sufficient likeness can be traced to justify a comparison with *Clathrodictyon*, and partially, it may be, with *Stylodictyon*. Here, in the genus *Cellepora*, the erect dichotomously branched species must be excluded, and only the globose spreading adnate forms taken into account. Even these latter seldom, if ever, assume the outward form of the Stromatoporoids, not excepting the recent *Cellepora mammillata*, with its incrusting polyzoarium and surface-projections. Their vertical or horizontal section in mass, though, does assume something of the cellulo-vesicular character of similar sections of *Clathrodictyon*. The heaping together and vertical inclination of the cells of the polyzoarium of *Cellepora* is, however, only a deceptive likeness; for even in the fossil species of the genus the punctured or sculptured character of the cell-walls, the presence of rostra, avicularia, ovicells, and often denticles, sinuses, or spines,

each, or all together, forbid the idea of identity with *Clathrodictyon* or its Stromatoporous allies. We have more especially directed attention to the above families of Polyzoa as those possessing the greatest likeness to the series of fossil forms at issue; for it is chiefly in the suborder Cheilostomata that the polyzoarium manifests skeletal likeness to most of the Stromatoporoids. Nevertheless we would remark that among the suborder Cyclostomata the genera *Heteropora*, De Blainville, and *Heteroporella*, Busk*, possess more than a usual amount of interest. Both have a surface furnished with openings of two kinds, viz. cell-orifices and tubes, the latter penetrating the polyzoarium vertically, and occasionally containing a kind of imperfect septa. These structural peculiarities are suggestive of *Caunopora*. Still they are deceptive resemblances; for in the Cyclostomata in question the canalicular cells or zoœcia run in close apposition alongside the tubular passages and in the same vertical direction, whereas in *Caunopora* the thick-walled tubes run diagonally to the laminæ and sarcode-chambers, besides others points of dissimilarity. In some species of *Heteropora* Mr. Busk mentions the presence of a superficial stellate appearance in connexion with the interstitial orifices; but what relation these may bear to the oblique radiating water-canals of the Stromatoporoids, we have not had the opportunity of accurately determining. It is sufficient for our purpose to show that, besides outward aspects, in other more important respects the diversity of structure establishes distinction between the Cyclostomatous Polyzoa and Stromatopora. Furthermore, as a whole, in zoœcia, oœcia, vibracula, avicularia, tubules, porous walls, and a variety of other minor particulars, the Polyzoa do not accord with any of the types of the Stromatoporoids.

Summary and Conclusion.

In this communication we have first given an epitome of the very diverse views held regarding *Stromatopora* up to the present time. We then treat of its fossil state, and show that, although the remains have been preserved in several mineral conditions, nevertheless the skeletal organization originally has been solely of a calcareous nature. We further contribute data bearing on the structural peculiarities, not only exteriorly and generally, but as elucidated by microscopic research. It results that neither are

* 'A Monograph of the Fossil Polyzoa of the Crag,' pp. 121 & 126.

the horizontal laminæ always porous nor the vertical pillars usually tubular, as some have asserted. In one peculiar aberrant form, *Caunopora*, there are, in addition, large, thick-walled tubes penetrating the mass vertically, and undoubtedly belonging to the organism itself. In some forms, notably the genus *Stromatocerium*, there is a system of more or less perpendicular canals and lacunæ without walls; in others there is a paucity or even absence of such, though, in most, smaller and larger apertures open superficially. A further system of stellate obliquely disposed canals exists, in many forms, both deeply and on the surface of the outer layers. While the typical *Stromatoporæ* are characterized by horizontal laminæ, supported by short upright pillars enclosing cuboid chambers or cells, some take on a vesicular character (*Clathrodictyon*), and others (*Pachystroma*) are destitute of pillars. Still other examples, essentially Stromatoporoid in aspect &c., assume a more indefinite minute structure, with a tendency to a reticulate or trabecular formation. In certain forms (notably *Stylodictyon*) a columnar character obtains, the chambers showing a concentric arrangement round a dense but reticulate centre. Thus by their intimate structural peculiarities we attempt a tentative classification, wherein we can distinguish at least seven types of construction which we rank provisionally as genera, and we describe *en passant* a few new and remarkable species.

In discussing the affinities of *Stromatopora* and its allies, we bring forward such evidence and argument as we believe is sufficient to warrant our excluding them in the meanwhile from alliance with the Nullipores, the Foraminifera, the Hexactinellid Sponges, the Polyzoa, the Corals, and certain fossil forms of uncertain affinities. As respects their Hydrozoal connexion we express ourselves with greater reticence, inasmuch as both in *Hydractinia* and *Millepora* not only are there certain superficial resemblances of considerable importance, but through the curious divergent form *Caunopora* structural peculiarities present themselves which possibly point to Hydrozoal relationships. Moreover, Mr. Carter's late very shrewd observations among the chitinous and calcareous *Hydractiniæ* necessarily render the subject at issue open to further research before the decided negative can be affirmed. Mr. Moseley's* able investigations on the *Hydrocorallinæ* during the 'Challenger' Expedition, while they yield valuable

* Philos. Trans. 1876, vol. clxvi. pp. 91–129, pls. 8 & 9.

hints, do not yet afford all that is desirable to unravel the knotty point. It is possible, though, that his future investigations of the ample material brought home may supply facts bearing more directly on the skeletal structure of the fossil Stromatoporoids. Lastly, respecting Sponge alliance, we are beset by obstacles, for neither do the Horny, Siliceous, nor Calcareous divisions, recent or fossil, so far as present knowledge extends, supply us with stable data whereon to assert identity. By reason of the nature of the skeletal basis, the two former groups are necessarily excluded; while total absence of spicules in the *Stromatoporæ*, as widely understood, renders it impossible to class them unconditionally with the Calcareous order of the Sponges. But seeing that Hydrozoa lconstruction, with its tubular zooidal cavities, tabulæ, &c., has not been shown to exist in the typical forms of the Stromatoporoids, and that neither in *Millepora* nor *Hydractinia* &c., so far as we are aware, does such a system of intercommunicating passages and occasionally lacunæ without walls obtain, as exemplified in *Stromatocerium* &c., we are constrained to adopt the parallel of the Siliceous sponges with fused and adnate spicules, and assume the existence in times past of a Calcareous group of the class Spongida with a continuous skeleton composed of non-spicular granular calcareous matter. We are, however, by no means prejudiced, but hold ourselves open to conviction; for if hereafter it be demonstrated that the canal-systems &c. of the *Stromatoporæ* are not normal productions, as we at present believe them to be beyond any reasonable doubt, but "branching canals bored by some low vegetable organism," as Moseley (*l. c.* p. 116) avers is the case in *Millepora* and *Pocillopora* &c., and, furthermore, that other structural Stromatoporoid peculiarities are present in undoubted members of the Hydrozoa, then we shall be willing to admit their alliance with the latter, though certainly they are aberrant types. With our present imperfect knowledge, and taking into account all the data for and against, we must at present regard them as a group *per se*, or, as we think justifiable on the positive and negative evidence, a new section of the Calcareous Sponges, for which we propose the term STROMATOPOROIDEA.

DESCRIPTION OF THE PLATES.

PLATE I.

Fig. 1. *Stromatopora tuberculata*, Nich. A small portion from the Corniferous Limestone, Jarvis, Ontario, showing, above, the roughened nodular or

tuberculate and granular surface, and also below, in side view, the (weathered) series of undulating layers composing the thickness of the specimen. About the natural size.

Fig. 2. Another, smaller, piece of *Stromatopora tuberculata*, exhibiting the surface of the concentric lamina, its granular intermediate structure and protruding pillars with pseudo-orifices, × 3 diam. (from the Devonian measures, Canada), and in which the skeleton has been silicified and the filling up of the chambers calcareous.

Fig. 3. A vertically exposed fragment of *S. tuberculata*, preserved in the same way and decalcified by weathering. The chambers, horizontal laminæ or concentric layers, and the vertical or radial pillars stand out in relief. × 3 diam.

Fig. 4. The form usually known as *Stromatopora striatella*, D'Orb. A transparent vertical section of an example from the Wenlock, Upper Silurian, Gotland, Sweden. Seen under a 2-inch object-lens (= ×20 diam.), and, as in fig. 3, exhibiting the chambers, horizontal laminæ, and radial pillars.

Fig. 5. A partly tangential and transverse section of the same piece of *S. striatella*, ×20 diam., and in which the cut ends of the radial pillars are very manifest.

Fig. 6. Another, chiefly vertical, section, but from the same specimen of *S. stritella*, under a 1-inch objective, ×60 diam. The granular character of the horizontal laminæ and vertical pillars, and the occasional intercommunication of the chambers by imperfection of the septa, are markedly visible.

Fig. 7. An oblique or tangential section of the so-called *S. striatella*, also viewed with an inch objective (= ×50 diam.).

Fig. 8. *Stromatopora nodulata*, Nich. A transparent vertical section of a piece from the Corniferous Limestone, Ohio. Twice nat. size.

Fig. 9. A portion of the above specimen of *S. nodulata*, under a 2-inch object-lens (= × 20 diam.). In this figure the irregularity in size and shape of the sarcode-chambers and variability in thickness of the concentric laminæ and vertical pillars are noteworthy. The specimen itself shows, what is barely represented in the drawing on stone, that both laminæ and pillars, but especially the former, are remarkably granular in consistence, and in many instances a series of subsidiary thin layers compose each lamina, or give it a somewhat reticulate porous appearance.

Fig. 10. *Stromatopora mammillata*, Nich. A small portion of the surface of an extensive thin crust, exhibiting its conical elevations, a few of which appear perforated. On the undulating granular intervening spaces, rather indistinct however, are traces of stellæ or radiate water-canals. From the Corniferous Limestone of Port Colborne. Nat. size.

Fig. 11. *Stromatopora* (*Cœnostroma*?) *granulata*, Nich. Stellar grooves or radiate water-canals with surrounding miliary granulation on the weathered surface of a portion of an undulating crust. Nat. size.

Fig. 12. *S.* (*Cœnostroma*?) *granulata*. A vertical transparent section, ×6 diam. This irregular-looking crust had grown and pushed its way among some coral débris. Magnified more highly, portions of this specimen still

better manifest the tendency to thin secondary horizontal arching among the chambers and laminæ.

Fig. 13. Tangential section of *S. granulata*, a small area under a 4-inch object-lens (= ×10 diam.). The irregular shapes, sizes, and disposition of the cut ends of the main and subsidiary laminæ bear out what has been said of fig. 12. This and the two preceding objects are from specimens obtained in the Hamilton group, Ontario.

Plate II.

Fig. 1. *Stromatopora ostiolata*, Nich. A vertical section of a segment of a hemispherical piece, × 6 diam.

Fig. 2. A tangential section of *S. ostiolata*; a limited area under a 2-inch object-lens (= × 20 diam.). This and fig. 1 are from the Guelph Limestones (Upper Silurian), Canada: they have been preserved in crystalline dolomite, and are both very imperfect in minute structure.

Fig. 3. *Cœnostroma discoideum*, Lonsdl.? An oblique transparent section under a 1-inch object-lens (= × 60 diam.). The slide was a poor one, by no means clear in outline. From the Wenlock Limestone, Gotland, Sweden; named by Lindström. It is uncertain if it be Lonsdale's *Heliolites? discoideus*; equally it is doubtfully a so-called *Cœnostroma* or true *Stromatopora*.

Fig. 4. *Caunopora planulata*, Phill., obtained from the Devonian, Babbicombe, Devonshire. A small segment of a partially vertical and oblique section, under a 4-inch objective (= × 10 diam.).

Fig. 5. A portion of the last vertical section (*C. planulata*) more highly magnified (viz. 2-inch objective, = × 20 diam.). Both show the calcareous thick-walled tubes partly lengthwise and cut across, and also the reticular concentric laminæ. Unfortunately none of the occasional interconnecting tubules have been shown in figs. 4 and 5.

Fig. 6. *Clathrodictyon cellulosum;* Nich. & Murie. Enlarged fragment, but natural appearance, of a weathered, opaque, vertical surface, showing sarcode-chambers &c., × 4 diam. The skeleton is here siliceous, and the calcareous filling of the chambers has been removed by the weathering process; the walls of the chambers everywhere exhibit quite a porous appeaarnce. Figs. 6 to 10 are from the Corniferous Limestone (Devonian), Canada.

Fig. 7. Natural casts in silica of the sarcode-chambers of *Clathrodictyon cellulosum*, × 4 diam. The calcareous skeleton has been removed by weathering; the surfaces of the interlaminar spaces are shown.

Fig. 8. A segment of a transparent vertical section of *C. cellulosum*, as seen magnified with a hand-lens (= ×2½ diam.).

Fig. 9. A portion of the same section of *C. cellulosum* under a 2-inch objective (= × 20 diam.). The conspicuous absence of radial pillars, other than as inflected cell-walls, and the occasional stretching of a thin partition obliquely across, may be noticed. (The artist has placed this figure so that the horizontal laminæ are in an upright position.)

Fig. 10. A tangential section of *C. cellulosum*, also under a 2-inch object-lens (= × 20 diam.).

Fig. 11. *Clathrodictyon vesiculosum*, Nich. & Murie. A vertical transparent

section, under a 1-inch objective (= ×60 diam.). The granular nature of the cell-walls is marked. Figs. 11–13 are from the Clinton formation (Upper Silurian), Ohio, and have been preserved in crystalline dolomite.

Fig. 12. A tangential section of *C. vesiculosum* under a 2-inch object-lens (= ×20 diam.).

Fig. 13. One of the stellate or radiate water-canals of *C. vesiculosum*, magnified with a pocket-lens (= ×4 diam.).

Fig. 14. *Stylodictyon retiforme*, Nich. & Murie. A few of the nipple-like elevations on the surface. About natural size.

PLATE III.

Fig. 1. A portion of a vertical section of *Stylodictyon retiforme* as viewed under a hand-lens (= ×3 diam.). This, the preceding, and two succeeding preparations are from specimens collected in the Hamilton formation (Devonian), Canada.

Fig. 2. Part of the same vertical section of *S. retiforme* under a 4-inch objective (= ×10 diam.). In figs. 1 and 2, vertical, and fig. 3, transverse, section, the more dense but reticular nature of the vertical columns is specially marked; and in the first two the very characteristic wavy laminæ and unequally lengthened vertical or radial pillars at once call attention.

Fig. 3. A transverse or slightly oblique section of the area composing one of the distinguishing vertical columns of *S. retiforme*, under a 4-inch objective (= ×10 diam.).

Fig. 4. *Stylodictyon* (*Syringostroma*) *columnare*, Nich. A horizontal or transverse polished opaque section. Nat. size.

Fig. 5. A vertical polished section of the same piece of *S. columnare*, also of nat. size, the light-coloured columns in this and the last being readily appreciable to the naked eye. Figs. 4–8 are from the Corniferous strata (Devonian) of Ohio.

Fig. 6. A vertical transparent section of a small segment of *Stylodictyon columnare* under a 4-inch objective (= ×10 diam.). The more solid nature of the columns and the flatter sinuosities of the laminæ as contrasted with the looser reticular structure of *S. retiforme* are very evident. In *S. columnare*, also, the laminæ are very numerous and closely set in layers.

Fig. 7. The area comprising a single circular column of *S. columnare* in transverse section, under a 2-inch objective (= ×20 diam.).

Fig. 8. An oval-shaped columnar area from another transverse section of *S. columnare*, ×20 diam.

Figs. 7 and 8 equally exhibit a comparatively solid centre, surrounded by nearly equidistant series of circular chambers, and these again encircled by a more or less continuous set of chambers which give the appearance of a bounding external ring. Between these columnar areas the sarcode-chambers are somewhat less regular and closer set.

Fig. 9. *Stromatocerium canadense*, Nich. & Murie. A vertical transparent section, ×2½ diam. Specimen got from the Trenton Limestone, Couchiching, Canada. The multitudinous, wall-less vertical tubes and

absence of the so-called vertical "radial pillars" are conspicuous characters.

Fig. 10. Sketch of a limited portion of another vertical section of *S. canadense*, examined with a 4-inch objective (= ×10 diam.). In this a large vacuity surrounded by granular matter is prominent.

Plate IV.

Fig. 1. *Pachystroma* sp.? Portion of the exterior undulating surface, of natural size, showing the superficial star-shaped depressions or "radiate water-canals."

Fig. 2. *Pachystroma antiqua*, Nich. & Murie. View of a small part of a larger specimen, of nat. size, exhibiting the wavy layers as seen in the exposed weathered condition. From the Upper Silurian (Niagara Limestone), Canada.

Fig. 3. A polished vertical section of a piece of *P. antiqua*, of nat. size, showing the contorted thick laminæ.

Fig. 4. A transparent microscopical specimen, being a vertical section of *P. antiqua*, about twice nat. size. In this the interlaminar structure is rather indefinite.

Fig. 5. A transverse or slightly tangential section of *P. antiqua*, also ×2 diam. The circular area appears to correspond to the nodular eminences (possibly stellate systems) of the exterior crust, and in some respects bear a partial likeness to the columns of *Stylodictyon columnare*, though by far larger. What the artist has represented in dark dotted lines and broken inner circle are under the microscope apparently sarcode-chambers, on the whole rather indistinct.

Fig. 6. *Pachystroma* (*Syringostroma*) *densa*, Nich. A vertical transparent section, ×2 diam. The sinuous layers in two places enclose sandy concretionary substance. The laminæ are relatively shallow and the small-sized chambers somewhat indefinite. From the Corniferous Limestone (Devonian), Ohio.

Fig. 7. View of a small portion of a tangential section of *P. densa*, under a 2-inch objective (= ×20 diam.).

Fig. 8. A vertical transparent section of what appears to be a Stromatoporoid from the Trenton-Limestone, Canada, and here represented of twice nat. size. There is a marked series of horizontal or concentric laminæ of average or considerable thickness. What appears to answer to vertical pillars are thin, linear, occasionally tubular-like threads, passing from one to two or more laminæ, and here and there joining each other so as to form oblong cells (=? sarcode chambers), these being filled throughout by crystalline matter. There are besides what correspond to columnar areas, which pass vertically upwards and seem formed of obliquely meeting cell (?) boundaries. The indefinite nature of this specimen makes us hesitate to describe it until further examination be instituted.

Fig. 9. A polished median vertical section of portion of another undetermined Stromatoporoid from the Cincinnati formation (Lower Silurian), Waynesville, Ohio. Drawn of nat. size, and placed in the Plate crosswise to what may have been its natural position—that is, it may origi-

nally have been of a conical figure, thrice, or thereabouts, longer than that here shown. The skeleton is completely silicified, and what appears to answer to cavities are infiltrated with silica. Both upper and lower surfaces are of a roughened nodular character, though the view here given represents the lower border as plane. Both margins for a short distance inwards are markedly in thin undulating layers; deeper and centrally the layers assume minor ovoid figures, and in many, if not all, are radiating lines or pillars therefrom. These ovoid centres appear to correspond to the exterior nodular elevations (see fig. 10).

Fig. 10. A limited part of the surface of the preceding Stromatoporoid (fig. 9), of nat. size, showing the nodose elevations, and that besides these granular, they bear evidence of stellar tracery in agreement with the oval interior designs.

Fig. 11. A vertical transparent section of a portion of fig. 9 under an inch objective (=×60 diam.). It is difficult to interpret the microscopic appearances here presented other than by supposing the larger dark areas as openings or expansions of an intricate system of tubulation. In other portions of the slide, but not here shown, there were indications of a network comparable with that of some of the Lithistid sponges.

Fig. 12. The exterior surface of one of the layers of a fragment of the fossil Polyzoon *Eschara nobilis*, Michelin, ×2 diam.

Fig. 13. A vertical section through a series of the layers of the same specimen of *E. nobilis*, also ×2 diam. These figures are introduced for comparison with the structure of *Stromatopora*, &c.; the vertical section displays a great general resemblance to similar sections of *Stromatopora*, inasmuch as horizontal layers and vertical pillars are present.

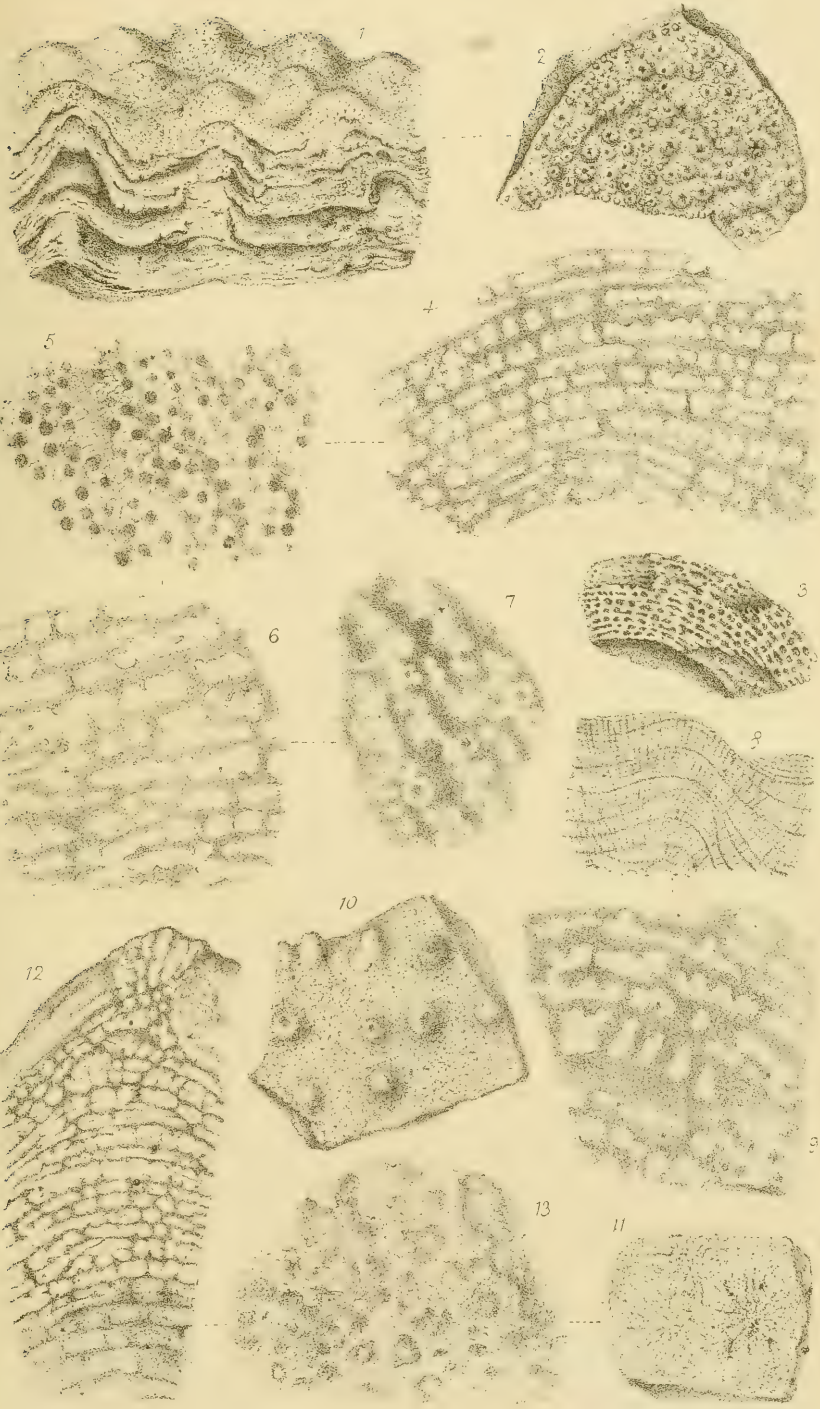
Description of New Species and Genera of *Eumolpidæ*.

By Joseph S. Baly, Esq., M.R.C.S., F.L.S.

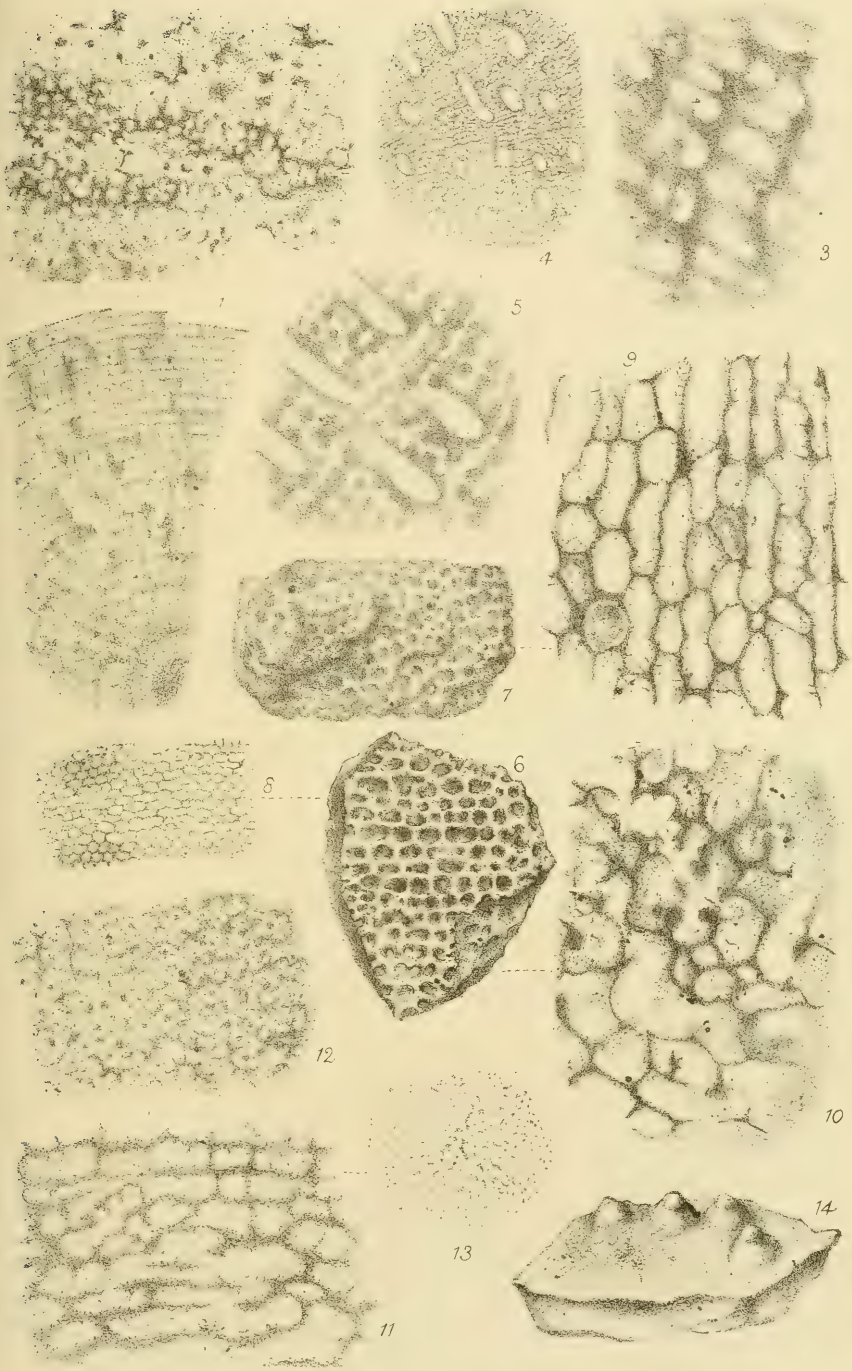
[Read December 20, 1877.]

List of Genera, Species, and their Habitat.

Aoria Mouhoti	Cambodia.
Eubrachis (n. g.) *spinipes*	Cameroons.
„ *indica*	Northern India.
Leprotes fulva	Tartary.
„ *Lewisi*	China, Japan.
Salodonta Simoni	Australia.
Parascela (n. g.).	
Cheiridea (n. g.) *Chapuisi*	Sierra Leone.
Colasposoma sellatum	Western Australia.
Ocnus pallidus	„ „



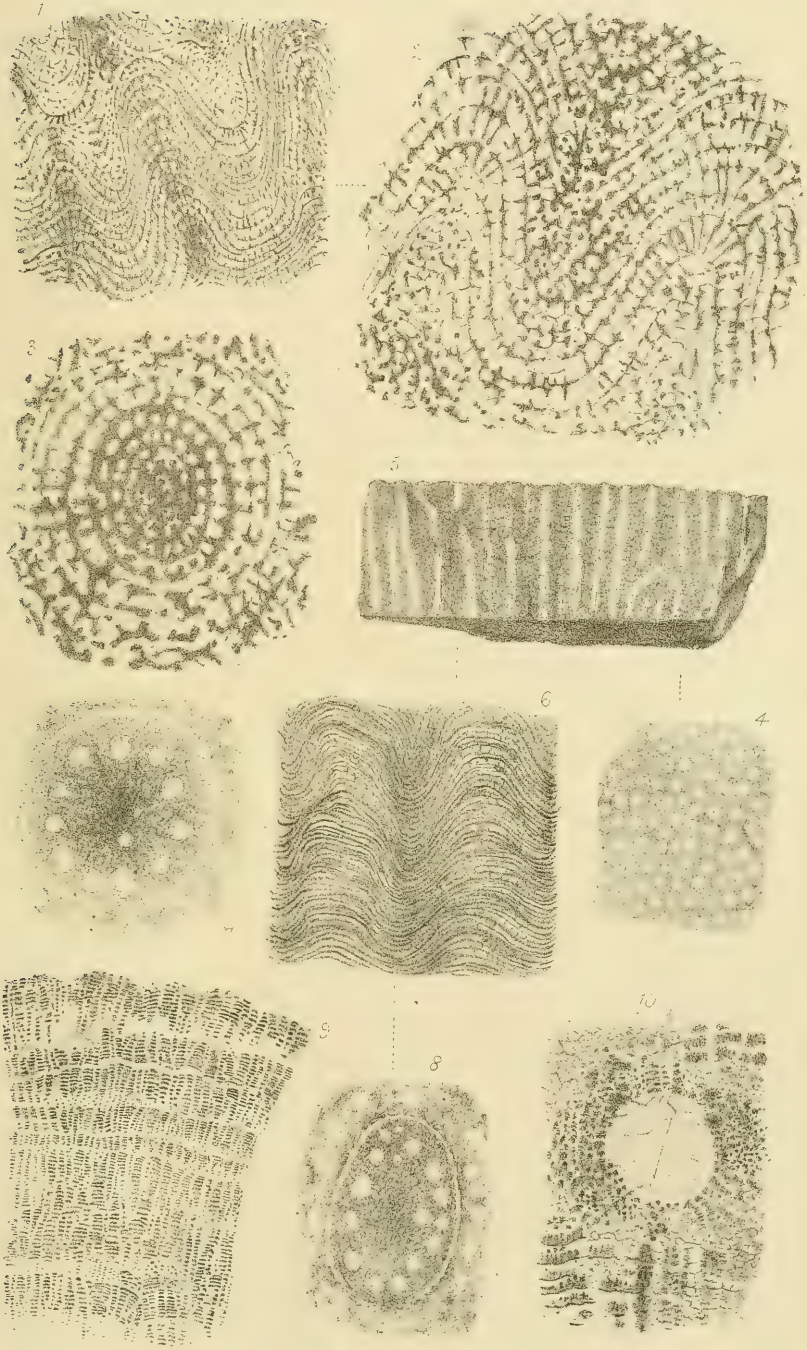
Berjeau lith. STRUCTURE SPECIES OF STROMATOPORA Hanhart imp



Berjeau lith.

STROMATOPORA, COENOSTROMA, CAUNOPORA, CLATHRODICTYON & STYLODICTYON

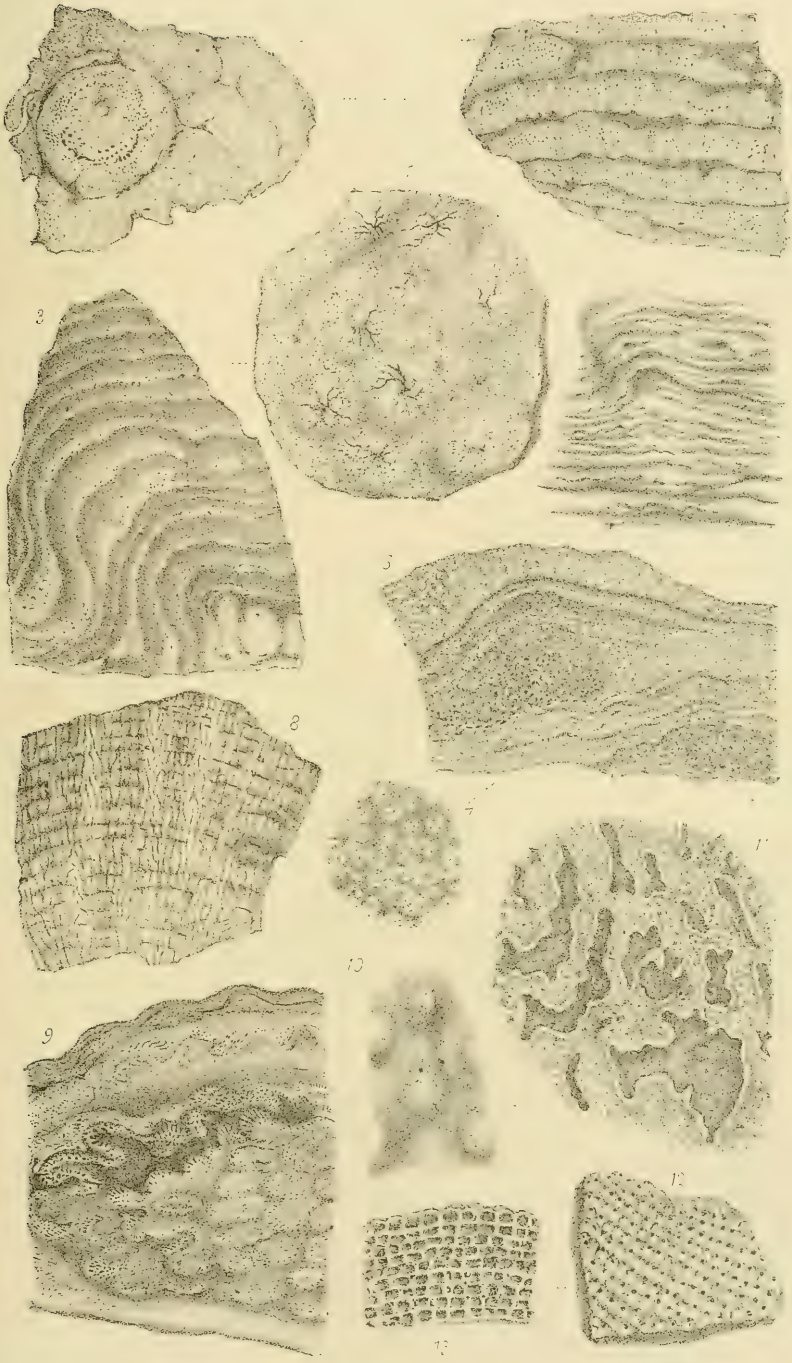
Palaeont. Soc.



Berjeau lith

STYLODICTYON & STROMATOCERIUM

Hanhart imp



PACHYSTROMA,
STROMATOPOROID & ESCHARA.

Berjeau lith. Hanhart imp